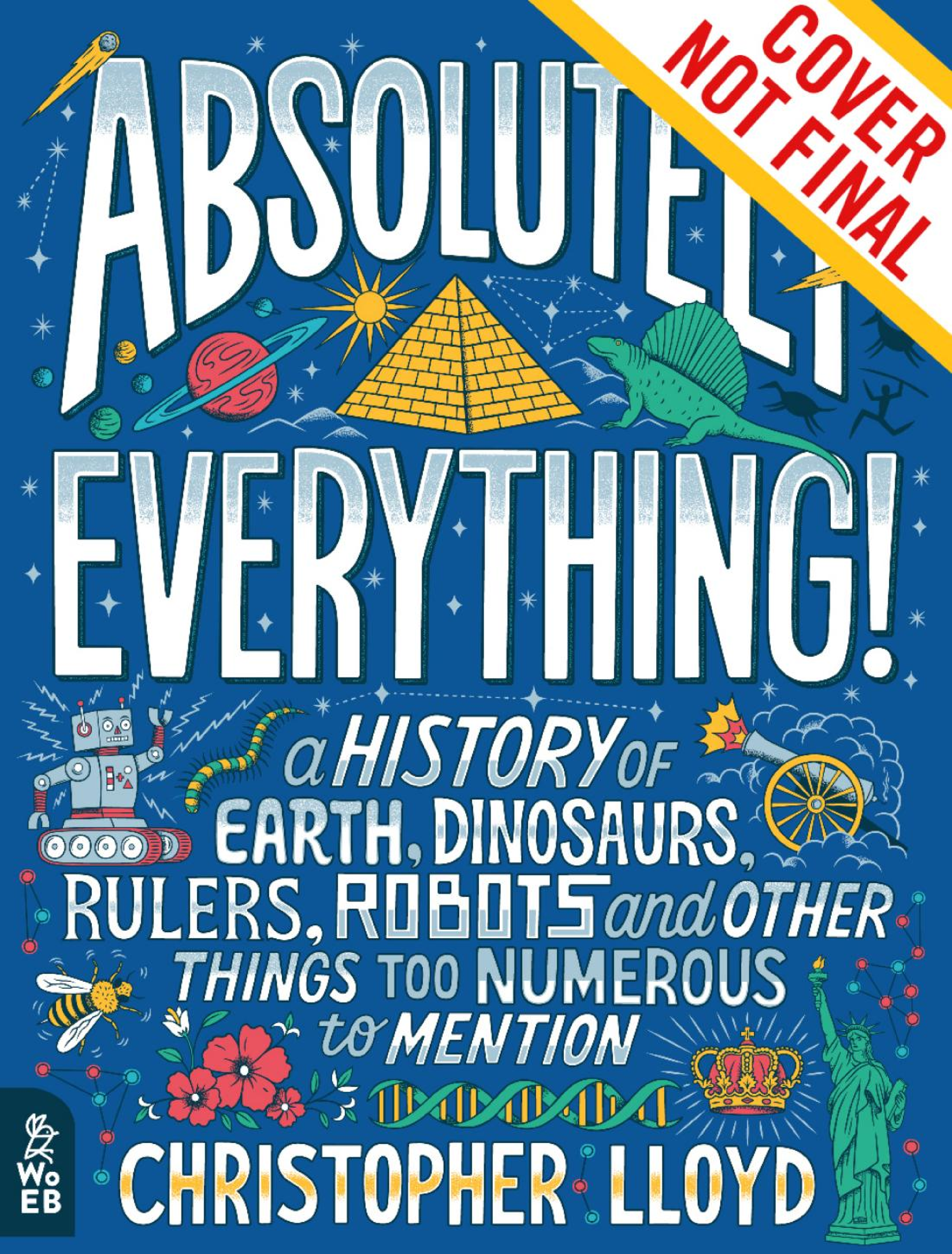

COVER NOT FINAL
ABSOLUTELY
EVERYTHING!
a HISTORY of EARTH, DINOSAURS, RULERS, ROBOTS and OTHER THINGS TOO NUMEROUS to MENTION
CHRISTOPHER LLOYD
WoEB

Contents

FOREWORD

Have you ever been on a family camping trip? Camping is one of the best things my family and I have ever done – we had such a lot of fun! If you have ever camped, you'll know there are quite a few different jobs that need doing every time you visit a camp site. As well as a few other chores, it was always my job to wash the dirty dishes.

It was OK. Actually, I started to enjoy washing up. As soon as I checked in at the washing up station, I could ask people what the place was like, where we should visit or, just as importantly, where we should *not* visit. So whenever I washed up my mind was always bursting with questions...

And then one day, just after we had arrived at a new campsite, I went to wash the dishes and, although there were loads of cars, tents and campervans, there was absolutely no one else there washing up. It was just me. All on my own.

I was gutted.

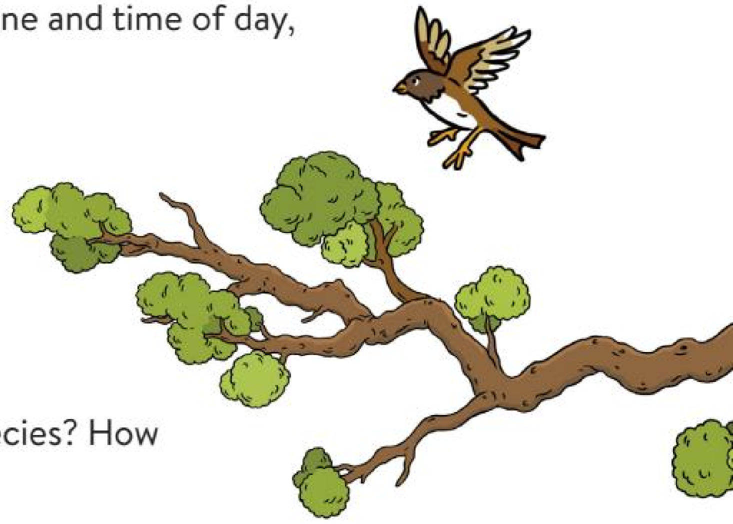
"Honestly," I thought. "How on earth am I supposed to do my research when there is no one here to talk to?"

And then I heard a tweeting noise coming from somewhere behind me. It was a beautiful day and, as with all the best campsites, the washing up station was open-air.

About 50 metres behind me I saw a bird high up in a tree. And then a thought struck me, that I will never forget.

If only I could speak Bird!

That creature, with its amazing wings, must have such a wonderful view of all that is worth seeing in the area. All that prevents me from finding out everything I want to know is a communication barrier. How frustrating to think that, despite us sharing the same air, the same sunshine and time of day, that bird and I could never talk.



Another thought then wriggled its way into my brain. Not only can I not speak *Bird* but I have no idea what kind of bird this is, twittering high up in that untouchable world of leafy green.

Small and brown, sure, but what species? How ignorant of me not to know!

Things got worse.

I looked at the tree. I had no idea what kind of tree it was.

I looked down at the ground.

I realized I didn't even have a clue as to how old the planet Earth is.

I was shocked and ashamed!

There I stood, having studied history and taken a job as a science writer on a leading national newspaper, yet I didn't seem to know the answers to questions about the simple, everyday things I was looking at! How much more everyday information was missing from my mind? How could I find out what I didn't know?

Now my head was spinning. I needed a book, something simple enough to understand but sweeping enough to connect together the dots of the past. My brain felt like it was a pane of shattered glass. Lots of bits, but if I were to take a step back, there was no big picture to make sense of it all.

After that camping trip I searched many bookshops, trying to find that simple guide to the history of everything.

The bookstore managers I quizzed said they had all the information, but that it was spread out among many different books...

"But I want it all in just one book that connects it together..."

"Sorry sir, I can't help you there..."

So that was it. I decided then and there to write this book.

Absolutely Everything: A History of Earth, Dinosaurs, Rulers, Robots, and Other Things Too Numerous to Mention will take you on an epic journey from the beginning of the universe, 13.8 billion years ago, all the way to the modern world we live in today.

I am hoping it will answer all kinds of questions you have. Some things you will already know and other things you will not. That's how it was for me when I did all the research and writing.

How old is the universe? What happened to the dinosaurs? When did humans first discover how to make fire? Why does climate change affect us all?

Of course this book doesn't really include *absolutely* everything everyone knows. That would take up more space than the whole internet. Instead the book is a portal to absolutely everything because for every question it answers, it sparks more questions,

which I hope will lead you well beyond the book into a life of questioning and finding answers.

So if you're the sort of person who loves to ask questions as much as you like to find answers, this story is the one for you. And *hold on tight* because there is one other really interesting thing I have found out along the way – the real world is far more amazing than anything you can make up!

Christopher Lloyd
June 2018

Oh, and by the way, since I came back from that camping trip I always wash up the dirty dishes at home, because, well, I have learned that you never really know what's going to happen next.

Chapter 1

Nothing to Something

13.8 billion–450 million years ago

Boom! The beginning of the universe, life and everything

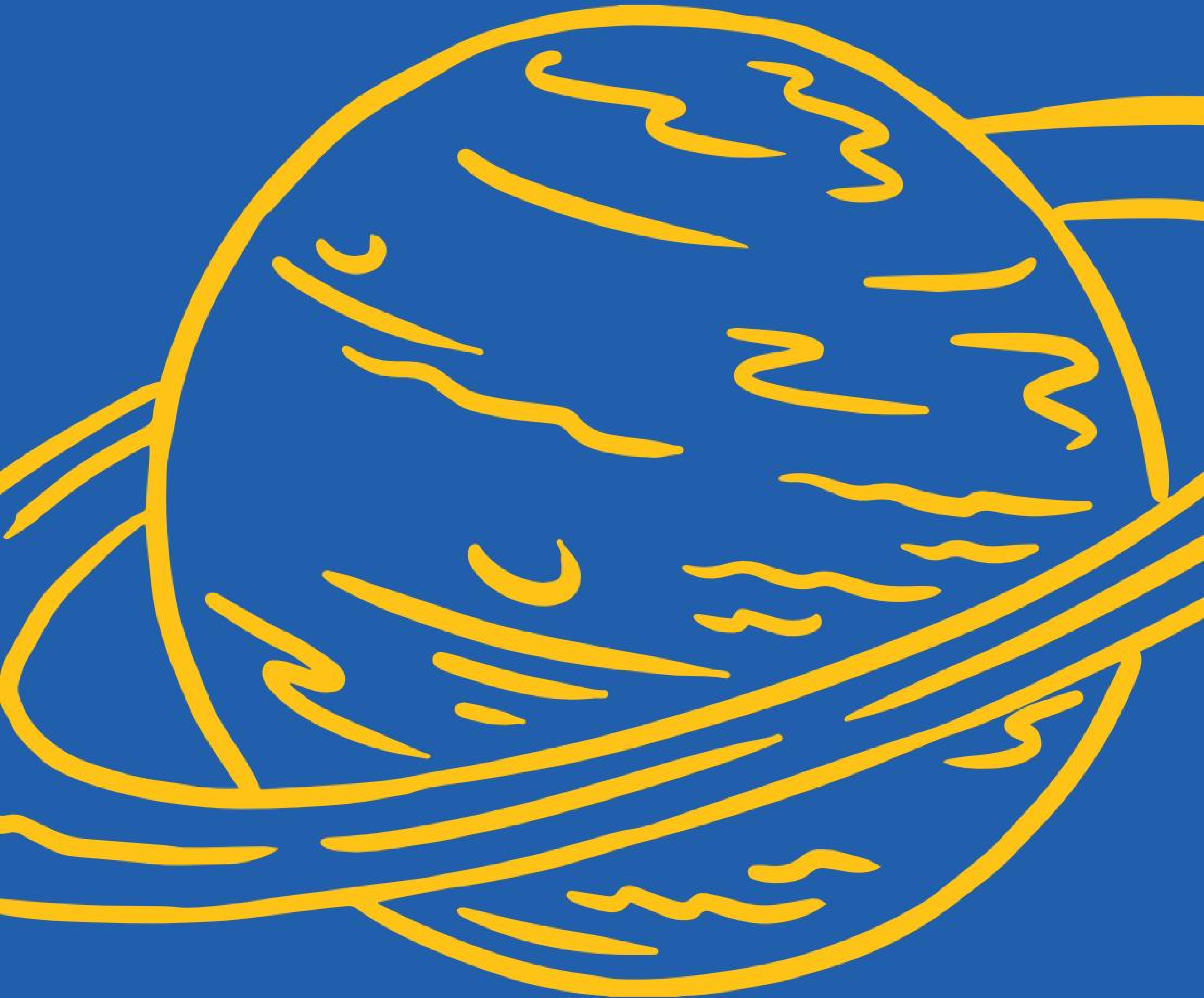
Timeline

13.8 billion years ago
Big Bang

13.6 billion years ago
Milky Way

4.6 billion years ago
The formation of the solar system

4.5 billion years ago
Planets collide forming the Moon



4 billion years ago
First signs of microscopic life in the seas

3.5 billion years ago
Plate tectonics begin shuffling continents around the planet

2.5 billion years ago
Cyanobacteria make oxygen and change the Earth's atmosphere forever

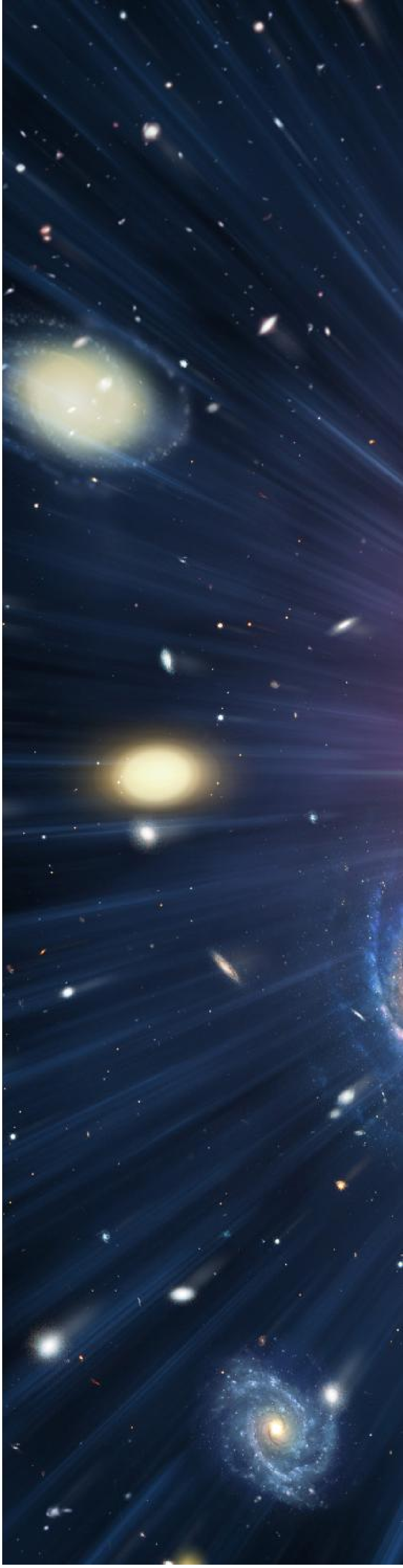
540 million years ago
Cambrian Explosion – species adapt or die in a world where some creatures can see

Take a good look around. Put everything you can see inside an imaginary but super powerful crushing machine. Plants, animals, buildings, your entire house, your home town, even the country where you live. See it all get mashed into a tiny ball. Now put the rest of the world in there too. Add the other planets in our solar system and the Sun.

Now put in our galaxy, the Milky Way, which includes about 200 billion other suns. Finally, add all the other galaxies in the universe. See all this stuff squeezed together to the size of a tennis ball. See it crushed even smaller than the dot on top of this letter i, until you can't see it at all. All those stars, moons and planets in a speck of nothing. That was it.

The universe began as an invisible dot. This dot was so hot and under such pressure from all the energy trapped inside it that something big was sure to happen. And about 13.8 billion years ago it did. It burst.

You've probably heard of the Big Bang – the theory that explains the beginning of the universe. But hang on a minute – the



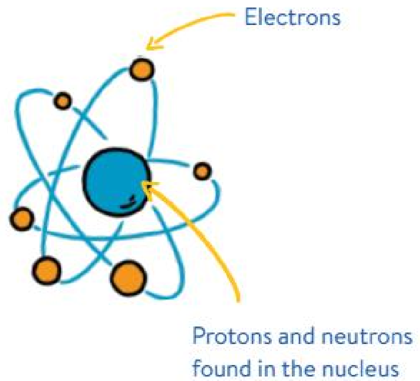
This picture shows how the Big Bang created everything from galaxies to stars as if we could see it all at once. But in fact, this happened over a huge amount of time.

beginning? That's what's so hard to understand. If the universe had a beginning, what happened before the beginning? No one really has an answer. As you'll see, there are plenty of mysteries that even modern science hasn't solved yet.

An infinite blast of energy was released when the Big Bang happened. Next came the basic forces of the universe, the ways all that energy interacts in space. Gravity is one of those forces. It is one of the most important because it makes all the stuff in the universe pull together.

> "YOU CAN'T GET TO A TIME BEFORE THE BIG BANG, BECAUSE THERE WAS NO TIME BEFORE THE BIG BANG."
>
> Stephen Hawking, physicist and author

Next came stuff itself. But it wasn't stuff the way we know it. It was countless too-tiny-to-see building bricks called subatomic particles. Think of them as miniature bits of Lego ready to build a whole wide universe. It's amazing to think that everything in the world is made out of billions of these subatomic particles created by the Big Bang. And that includes the furniture in your home and the hair on your head.



An atom is made up of subatomic particles.

About 380,000 years after the Big Bang, the universe cooled down enough so that the subatomic particles stuck together to make larger (but still too-tiny-to-see) structures we call atoms. Then, with the help of gravity, these atoms eventually gathered into giant clouds of very hot dust. As all those atoms were crushed together, they lit up as the first

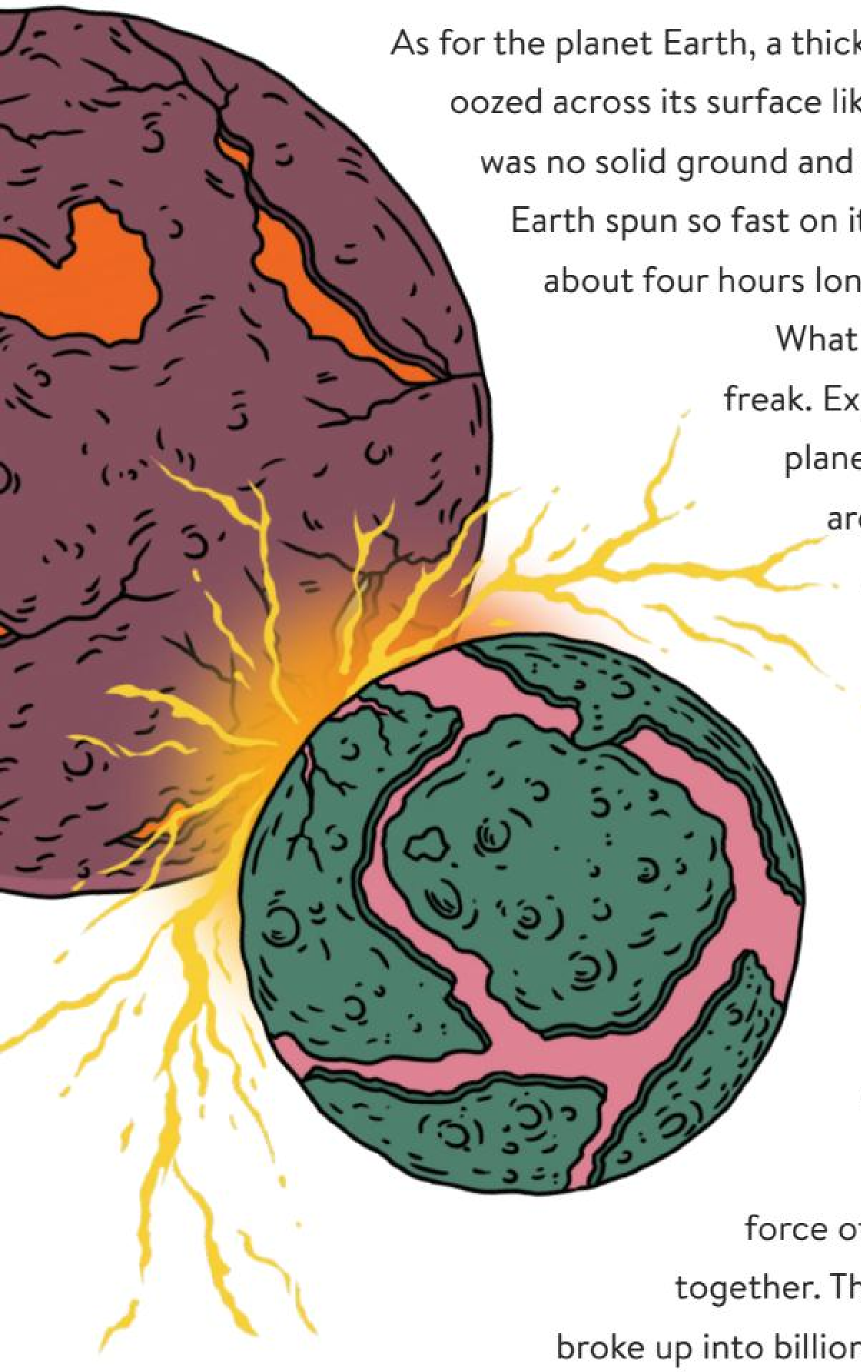
stars. That's what stars are. They are great balls full of atoms and energy left over from the Big Bang.

Stars gathered together into galaxies of many shapes and sizes. Stars were born and stars died. More stars were born. More stars died. Then, about 4.6 billion years ago, about two-thirds of the way through the history of the universe, the leftover gas and dust cloud from some old burned-out stars crushed together and lit up to form a new star. We care about this one the most. It's the one closest to our home, the Sun. And our planet, along with several others, was formed at about the same time as the Sun from a mixture of leftover dust and rock.

For a long time, people thought that the Earth was at the centre of the universe. But we now know that's not true. Our Sun and its planets are in the outer reaches of one of the Milky Way galaxy's arms, spinning around the centre of the galaxy at about 500,000 miles (800,000 km) per hour. You can't feel how fast you're going because our whole solar system is travelling with us at the same speed.

The Sun's solar flares are deadly to all living organisms, but the Earth is protected by its atmosphere.

The early solar system was totally unsuited to life. You couldn't have survived there for an instant. An invisible rain of tiny deadly particles poured out of the sun like a storm of razor-sharp daggers.


The Earth and Theia colliding

As for the planet Earth, a thick, melty crust of sticky lava oozed across its surface like boiling hot treacle. There was no solid ground and definitely no life. The early Earth spun so fast on its axis that each day was only about four hours long.

What happened next was a total freak. Experts believe that two young planets were on the same orbit around the Sun but moving at different speeds. One was the Earth. The other was a smaller planet called Theia. You can guess what happened next. Incredible as it sounds, about 100 million years after the Sun began to glow, these two new-born planets smashed into each other.

Just think of the crazy force of two planets crashing together. Theia's outer layers instantly broke up into billions of tiny particles. They covered the Earth with a thick blanket of hot dust and rock. Volcanoes erupted all over the Earth. Tons of gas that had been trapped inside the Earth's core blew out into the sky, making our planet's early atmosphere.

Actually, it's just as well for life on Earth that this great collision happened. Remember those tiny deadly particles that poured out of our Sun? Well the storm never stopped. Even today about twenty billion tonnes spew out in just one day. This scary stuff is known as the solar wind. It can go through even space suits and helmets worn by astronauts.

But it doesn't hurt us on Earth. That's because Theia and the Earth smashed into each other. When that happened, the huge shockwave fused the two planets' cores into one hot metallic ball. Ever since, this core has acted as a magnetic shield that keeps the lethal solar wind away from our planet's surface. The shield also keeps the world from losing its precious supplies of water, which otherwise would have been blown into space. No liquid water, no life. It's as simple as that.

> "THEIA IS THE SACRIFICE THAT PERHAPS HAD TO BE MADE, SO THAT LIFE AS WE KNOW IT COULD EVOLVE ON EARTH..."
>
> Dana Mackenzie, author of *The Big Splat*

Today there is no physical evidence on Earth of this dramatic collision. There is no crater because the force of the impact made all the outer material vaporise into space as dust. That dust wrapped itself around the Earth in a great cloud, which eventually stuck together again thanks to gravity. Can you guess what this enormous cloud of dust turned into? Of course! It became our beautiful heavenly companion – the Moon. The Moon has no atmosphere, which means it's not protected from the solar wind. It also means no sound can be heard on the Moon, and that the sky is always black.

Scientists are still unsure about lots of things to do with the early history of our planet Earth. That's because the Earth has changed so much over time that there's nothing much left of that early time for us to study. But they can look at how the world works and come up with some good guesses.

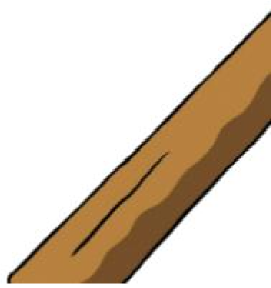
Of all the planets in our solar system, Earth is the only one with such a large amount of liquid water. Why does our particular world contain so much water? Where did it all come from? Because without water life can't develop, these questions are really important.

Some experts think water came from deep inside the early Earth. Others have a much more other-worldly idea. They think that more than half of the world's water may have arrived on giant icy comets or asteroids about 4 billion years ago.

Just imagine a storm of thousands of giant objects, some more than 100 miles (160 km) wide, smashing into the early Earth. As they scorched through the Earth's atmosphere, the ice on them melted, producing vast amounts of water. All that water still exists today. It's mostly in our giant global oceans. That's something to think about next time you take a bath. More than half the water in your tub possibly came from outer space.

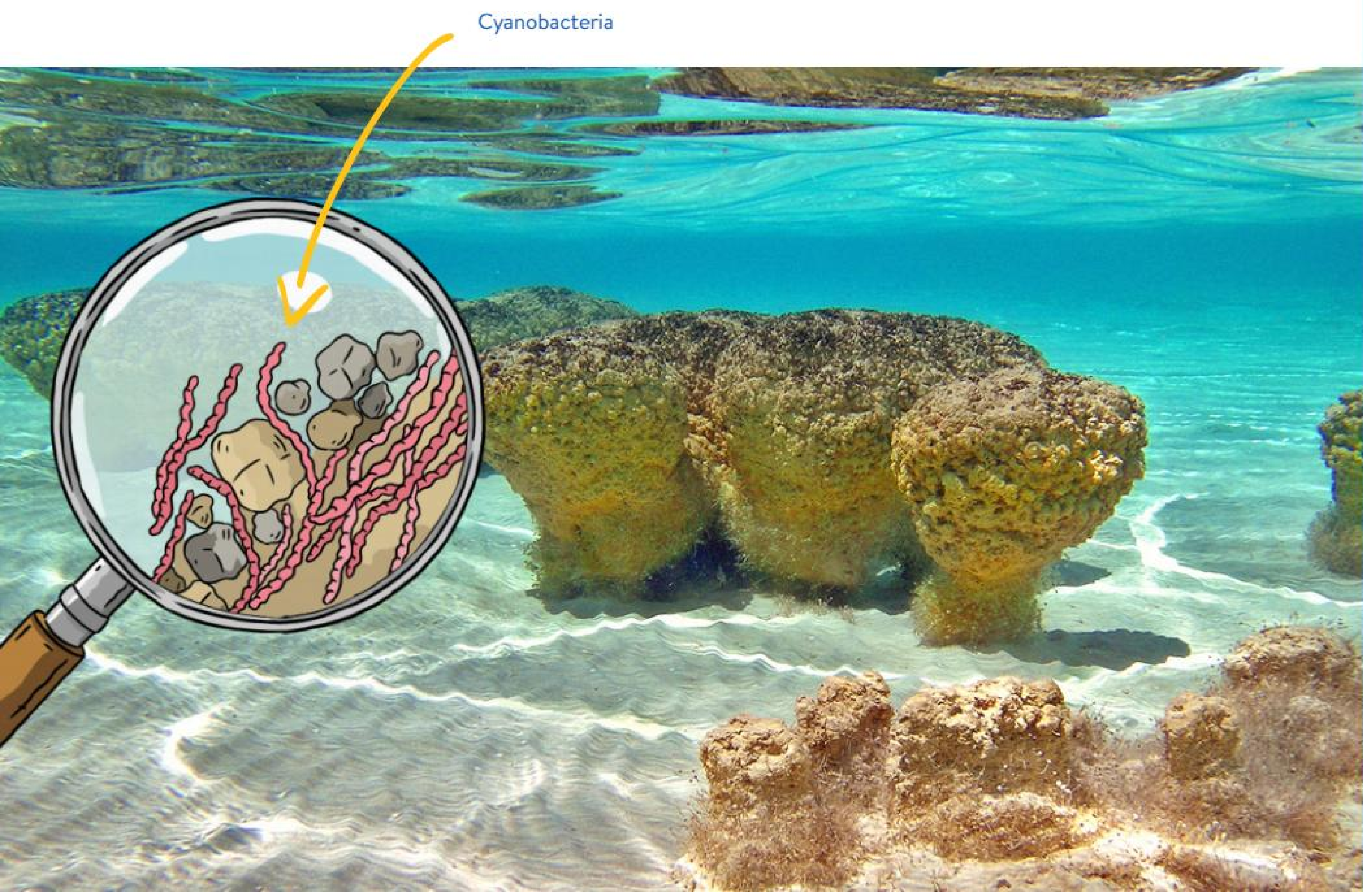
Plants, trees and animals are all here thanks to oxygen in the air and in our oceans, originally given off by cyanobacteria as waste. The picture on the right shows stromatolites in Shark Bay, Australia, where stromatolites can be found today.

How and where did life begin? This is another question that scientists don't quite agree on. Some experts think the stuff needed by the first living things may have arrived on those comets or asteroids from outer space. But most of them think that life started somewhere deep down at the bottom of the seas. There,

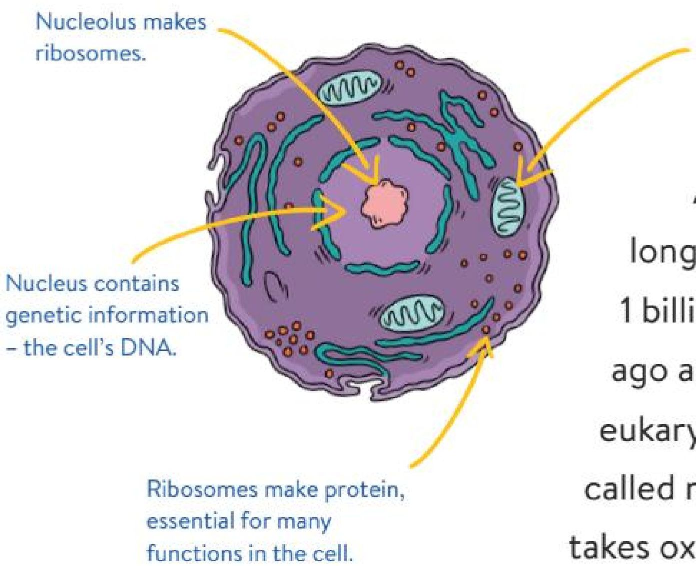


underwater volcanoes provided chemical food and warmth for teeny tiny living things. These life forms were just one cell, one tiny bundle of material that could eat, grow, and – most important – split in half to become two teeny tiny living things. That's what makes something alive, the ability to make more of itself.

As time passed, some single-celled lifeforms called cyanobacteria found a way to survive nearer the surface. They grouped together in shallow waters to make bumpy formations called stromatolites. They also used photosynthesis. It's the same process plants use today, to turn sunshine, nutrients and water into the energy they needed to survive. And just like all living things, they gave off waste. But this waste was pretty special. That's because cyanobacteria pooped oxygen. Yes, that's right, these tiny bacteria filled the air and the seas with oxygen, completely changing the story of life on Earth.



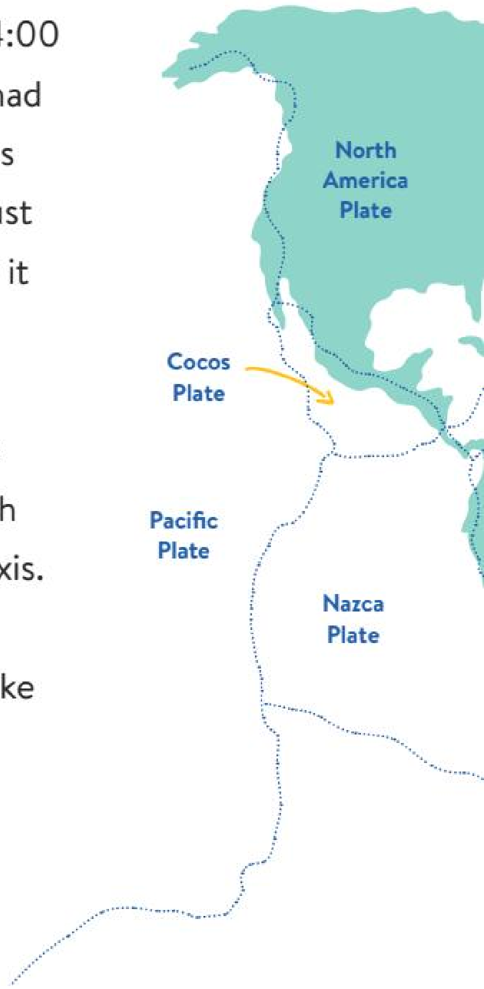
A eukaryote is an organism whose cells contain a nucleus.



All this world-changing took a long time. Let's move forward another 1 billion years. It's about two billion years ago and a new type of lifeform called eukaryotes is emerging. They use a process called respiration, or breathing. Respiration takes oxygen in to use as an ingredient to make energy. This marks another big change in the story of life on Earth. As you might have guessed, we humans are eukaryotes.

Imagine the Earth's history on a 24-hour clock. The Earth formed right at midnight. The first signs of life emerged at about 5:19 in the morning. But already we have travelled to nearly 4:00 in the afternoon. Amazingly, all the life on Earth that had existed until that point were these lifeforms in the seas that were too small to see. That leaves only 8 hours (just one-third of the day) for all the rest of life as we know it to emerge.

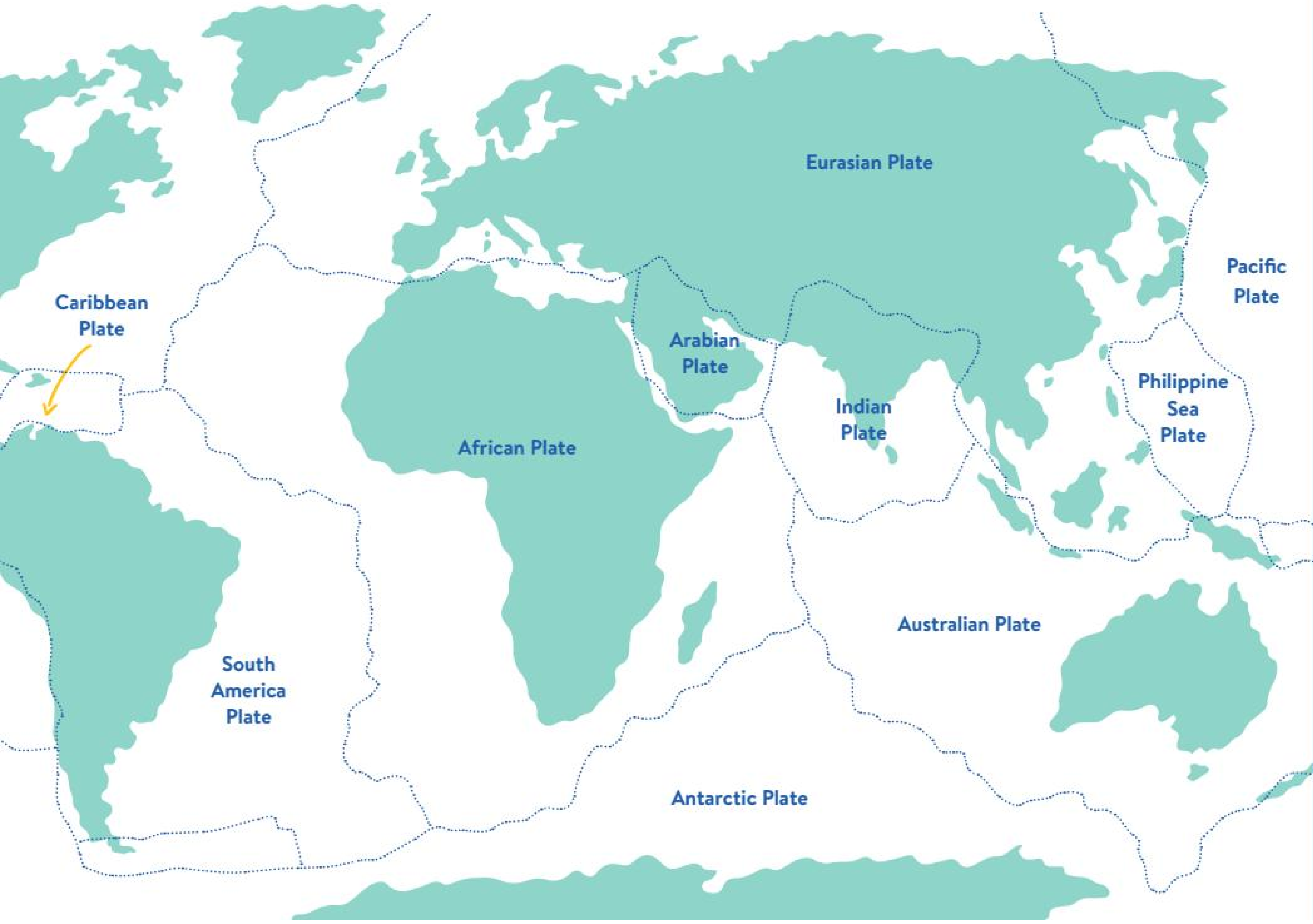
Remember how the earth travels with the solar system around the Milky Way far faster than any race car? Well, we are moving in other ways, too. The Earth is travelling around the Sun, and it is spinning on its axis. And there's yet another kind of movement. You are sitting on a crust of rock that is *very slowly* floating, like



a giant raft, on an underground sea of boiling-hot lava. With all this travelling and spinning and floating, nobody ever really sits still!

The Earth's surface is divided into moving pieces of land. The pieces are constantly drifting apart or bashing into one another, like bumper cars at a fun fair. It's a process called plate tectonics, and the pieces are called tectonic plates. When continents riding on these plates collide, they form mountain ranges soaring high up into the sky. When they drift apart, they form huge oceans or deep valleys. This gradual movement of the Earth's plates is so powerful that it creates earthquakes and volcanoes, geysers and tsunamis.

As you read this, you are sitting on a crust which is floating like a giant raft on an underground sea of boiling-hot lava. Here are how the Earth's tectonic plates are shaped today.



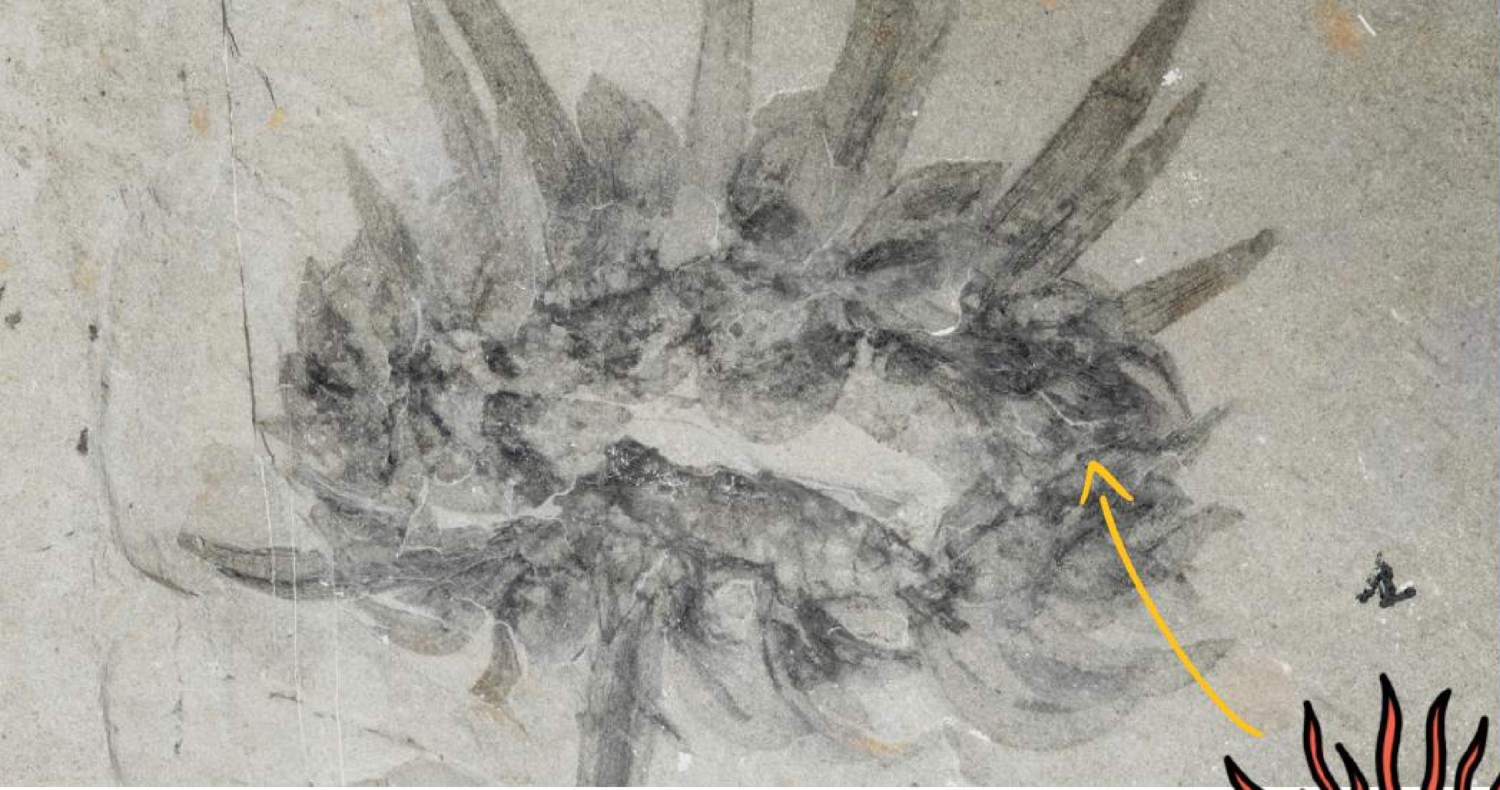
But there is a positive side to this violent process, too. The amount of salt in the seas has to be just right for life to survive. If the sea gets too salty, living things die. Thanks to the constant movement of the Earth's plates, salt gets buried deep beneath mountain ranges. This process removes salt from the seas, leaving the saltiness low enough so it's safe for life.

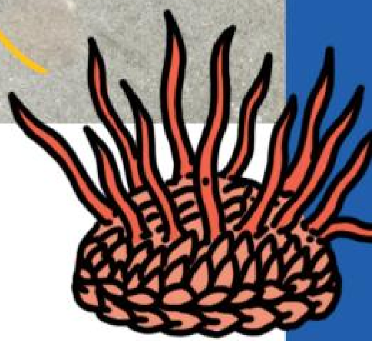
These moving plates also change the climate. Some scientists believe that about 650 million years ago, moving plates plunged the Earth into a super cold ice age.

This period is known as Snowball Earth. Ice gripped the globe all the way from pole to pole. When the weather eventually warmed up again and the ice retreated, the story of life took a new direction. There were still plenty of microscopic lifeforms. But now larger creatures made of many cells began to join them in the seas.

This is one of the most amazing moments in our story. It is 540 million years ago. A quick check on our 24-hour clock shows it's now just after 9:00 p.m. There are still no plants, no flowers, no birds or animals or humans. But finally, finally the first of the kind of lifeforms that will one day lead to the familiar world around us are starting to appear.

The mean global temperature during the Snowball Earth period was about -50°C. Now that's chilly!





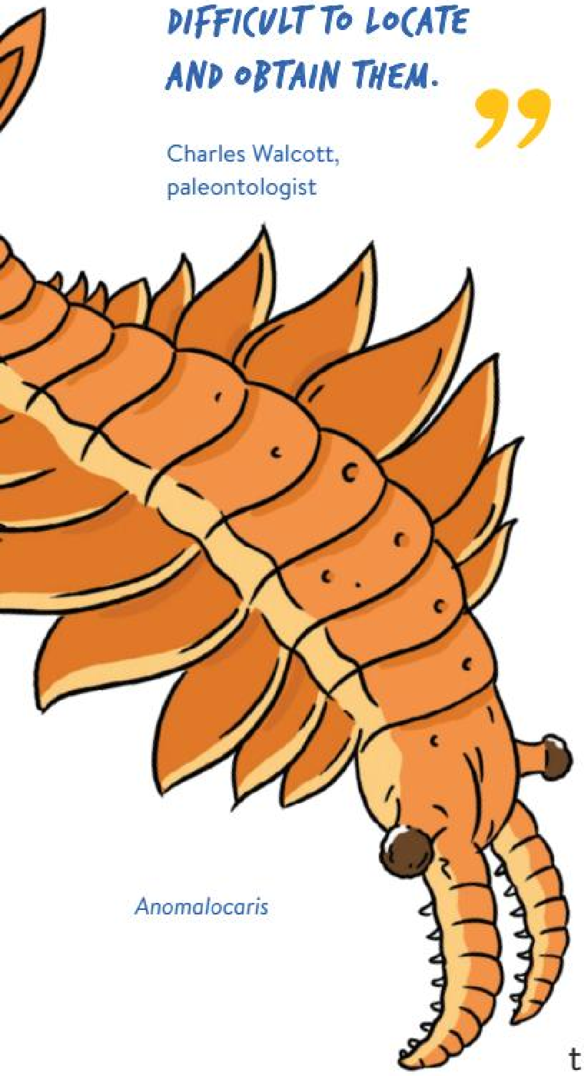
Walcott found fossils of a spiky mollusc called *Wiwaxia* in a place in Canada known as the Burgess Shale.

Fossils are the imprints of long-lost creatures, usually the hard parts of them such as bones, shells or teeth. When these creatures die, usually their bodies rot or dissolve. But sometimes, as the mud in the ground or on the sea floor turns hard, the cells that make up their hard parts can be replaced by minerals, turning them to stone. Fossils are wonderful for helping scientists understand what kinds of creatures once lived on the Earth. Expert fossil hunters are called paleontologists.

Charles Doolittle Walcott was a palaeontologist. He was born in upstate New York, in the United States, in 1850. As a young boy he found school quite boring. It wasn't that he had no interest in things, rather the opposite. He was so curious that he wanted to get outside and explore the world for himself – in particular he liked to look for minerals, rocks, birds' eggs and fossils.

> **NATURE HAS A HABIT OF PLACING SOME OF HER MOST ATTRACTIVE TREASURES IN PLACES WHERE IT IS DIFFICULT TO LOCATE AND OBTAIN THEM.**

Charles Walcott,
paleontologist

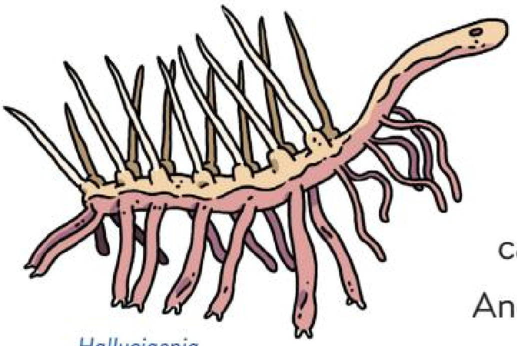


Anomalocaris

One day in 1909 a freak accident changed the rest of Walcott's life. The way some people tell it, he was walking high up in a remote part of the Canadian Rockies, and his horse slipped and lost a shoe. As the creature stumbled, its foot turned over a glistening rock. Walcott picked it up and saw a row of remarkable silvery fossils. These showed the perfectly preserved shapes of creatures dating back to a time known as the Cambrian Period.

Remember how the land is always moving and changing? Well, it turned out that the mountainside Walcott was standing on had been on the sea floor 505 million years ago. Way back then, something – maybe a mudslide – had killed these creatures and preserved them like a time capsule. Walcott's fossils are some of the oldest ever found. The place where he found them is known as the Burgess Shale, named after nearby Mount Burgess. Walcott returned to the site many times and eventually wrote a shelf of books about his finds.

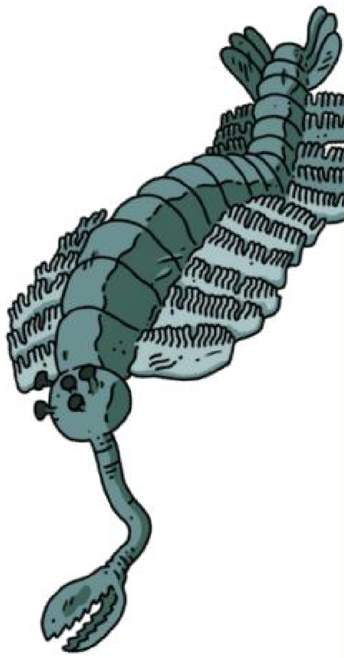
And what a bizarre range of creatures they were! There was the strange-looking *Anomalocaris*. Possibly the biggest hunter of its day, it could grow up to a metre long. It used a pair of grasping arms to



Hallucigenia

capture and hold its prey.

Another was *Hallucigenia*. This worm-like beast walked on tentacle-like legs. It used the spines on its back to protect itself from being eaten by predators.



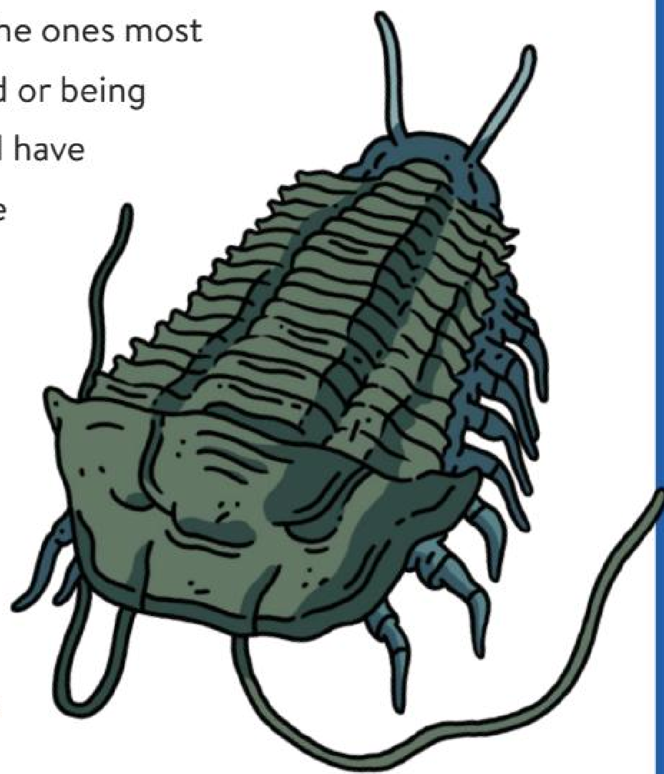
Opabinia

But nothing can prepare you for *Opabinia*. This oceanic oddbod had five eyes, a fan-like tail for swimming and a long, grasping nose with a mouth on the end for feeding. There's nothing remotely like it alive today.

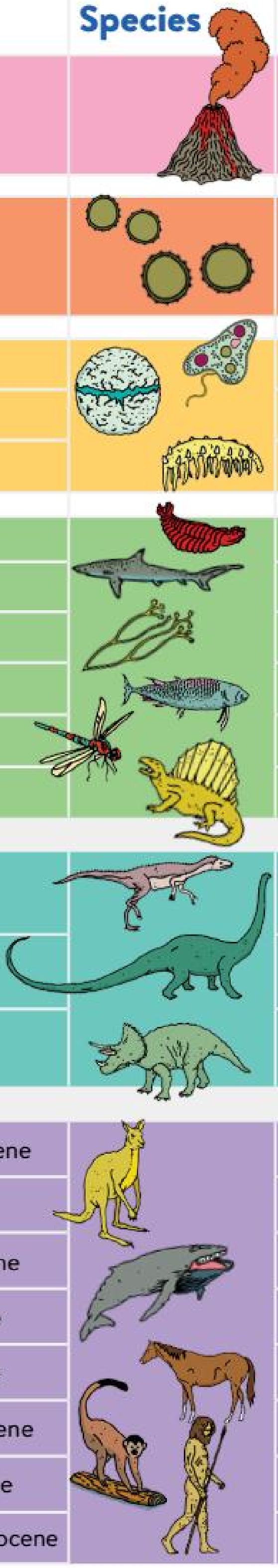
Another of the Cambrian Period's most common forms of animal life were beetle-like sea creatures called trilobites. Their fossils are up to three-quarters of a metre long and have been found all over the world. The most important thing about them is that they were likely the first creatures ever to have eyes.

Some experts think when trilobites developed eyes, it started a new race for survival in the ancient seas. They could choose what they wanted for dinner by looking around. Of course, creatures that were easy to see were the ones most likely to be dinner. Hiding underground or being the same colours as the seafloor would have been good ways to survive in this brave new world. This is a great example of how nature works, how new creatures replace old ones over time.

The Burgess Shale creatures gives us a view into the very beginning of a time called the



Trilobite



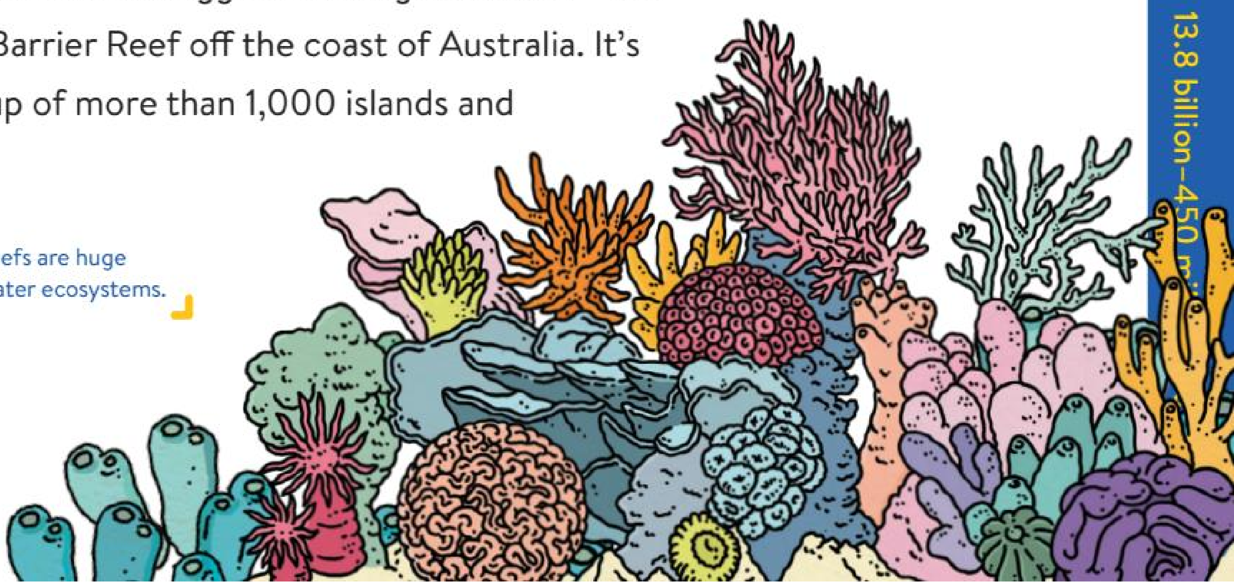
Millions of years ago	Era	Period	Epoch	Species	Evolutionary stage	Twenty-four-hour clock
4,600	HADEAN				No life on earth; volcanoes; rain cools the surface; oceans form.	00:00
3,800	ARCHAEAN				Methanogens (prokaryotes); cyanobacteria; stromatolites; oxygen in air.	04:00
2,500	PROTEROZOIC				Complex cells (eukaryotes).	15:00
850		Cryogenian			Snowball earth.	
635		Ediacaran			Multi-cellular creatures.	
542	PALAEOZOIC	Cambrian			Shells, bones and teeth.	20:50
488		Ordovician			Vertebrates.	
443		Silurian			Primitive land plants; worms.	21:50
416		Devonian			Bony fish; tetrapods.	
359		Carboniferous			Amphibians; reptiles; forests; flies.	
299		Permian			Mammal-like reptiles; Pangaea.	
251	MESOZOIC	Triassic			First dinosaurs; small mammals; ichthyosaurs.	22:50
199		Jurassic			Dinosaurs dominate land; pterodactyls in the air.	
145		Cretaceous			Last dinosaurs; social insects; flowers; birds; monocots.	
65.5	CENOZOIC	Tertiary	Palaeocene		Mammals grow larger.	23:40
55			Eocene		Whales return to the oceans.	
33			Oligocene		Horses evolve in Americas.	
23			Miocene		Monkey migrations.	
5			Pliocene		First bipeds and humans.	23:57
1.8	HISTORIC	Quaternary	Pleistocene		Megafauna extinctions.	23:59
0.11			Holocene		Farming; first human civilizations.	
0.02			Anthropocene		Globalization; rise in CO2 levels.	
today						24:00

Over time, many living things developed and died out. Looking at fossils and the rocks they're imbedded in helps scientists figure out when each one lived. Here's a chart showing time from the formation of the Earth to the present day and what we call each period of time that has passed.

Palaeozoic Era. There have been lots of fossils found from this era, which saw an explosion of incredible life in the seas. Let's go on an imaginary dive to check out some creatures who lived in the first part of the Palaeozoic, periods called Cambrian, Ordovician, Silurian and Devonian. Before we start, another quick time check on our twenty-four-hour clock of Earth history shows that this time lasts from 9:05 to 10:00 p.m.

Sponges were among the simplest of all animals living in the ancient Cambrian seas. They are still alive today. About 5,000 different species of sponge have been discovered so far. For a long time people thought sponges were plants, but actually sponges are animals. In fact, you and I are much more closely related to a sponge than to, say, a daffodil.

Coral reefs are built over hundreds of thousands of years by tiny sea creatures. The corals grow on top of the skeletons of their dead ancestors. With their bodies, they create a rich habitat for other creatures. Today up to 9,000 different species camp out in the Earth's biggest existing coral reef – the Great Barrier Reef off the coast of Australia. It's made up of more than 1,000 islands and



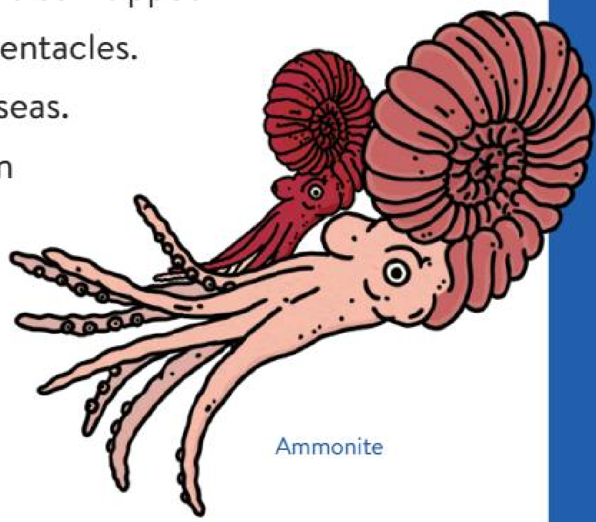
Coral reefs are huge underwater ecosystems.

Jellyfish like this one, which is a sea nettle (*Chrysaora fuscescens*), have been in the ocean for around 650 million years. Did you know that if a jellyfish is cut into two, it can regenerate and turn into two new jellyfish?

stretches for more than 1,400 miles (2,250 km). The ancestors of today's corals first appeared in the Cambrian period.

Jellyfish are part of the same family as corals but are nowhere near as friendly. They swim using a pumping action of their bell-like heads. Jellyfish have a very simple nervous system and only one opening – a combined mouth and bottom. And watch out! Some can pack a nasty punch. They use an array of poison-tipped harpoons hidden in stinging cells along their tentacles. Jellyfish were very common in the Cambrian seas.

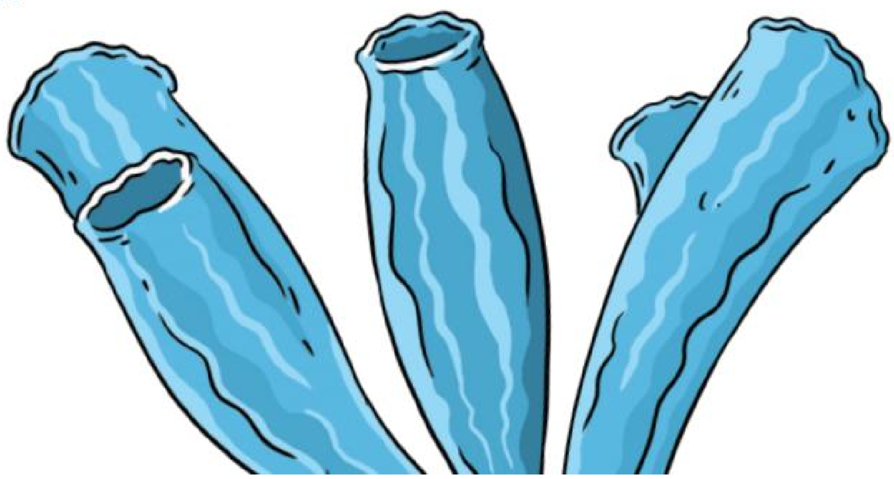
Ammonites appeared during the Devonian period and went extinct 65 million years ago, at the same time as most dinosaurs. They looked like giant snails, but their closest living cousins are octopus and squid. Ammonites had spiral shells to help protect them against attack. We know those shells came in handy. Their fossils have been found all over the world showing teeth marks and scars.



Ammonite

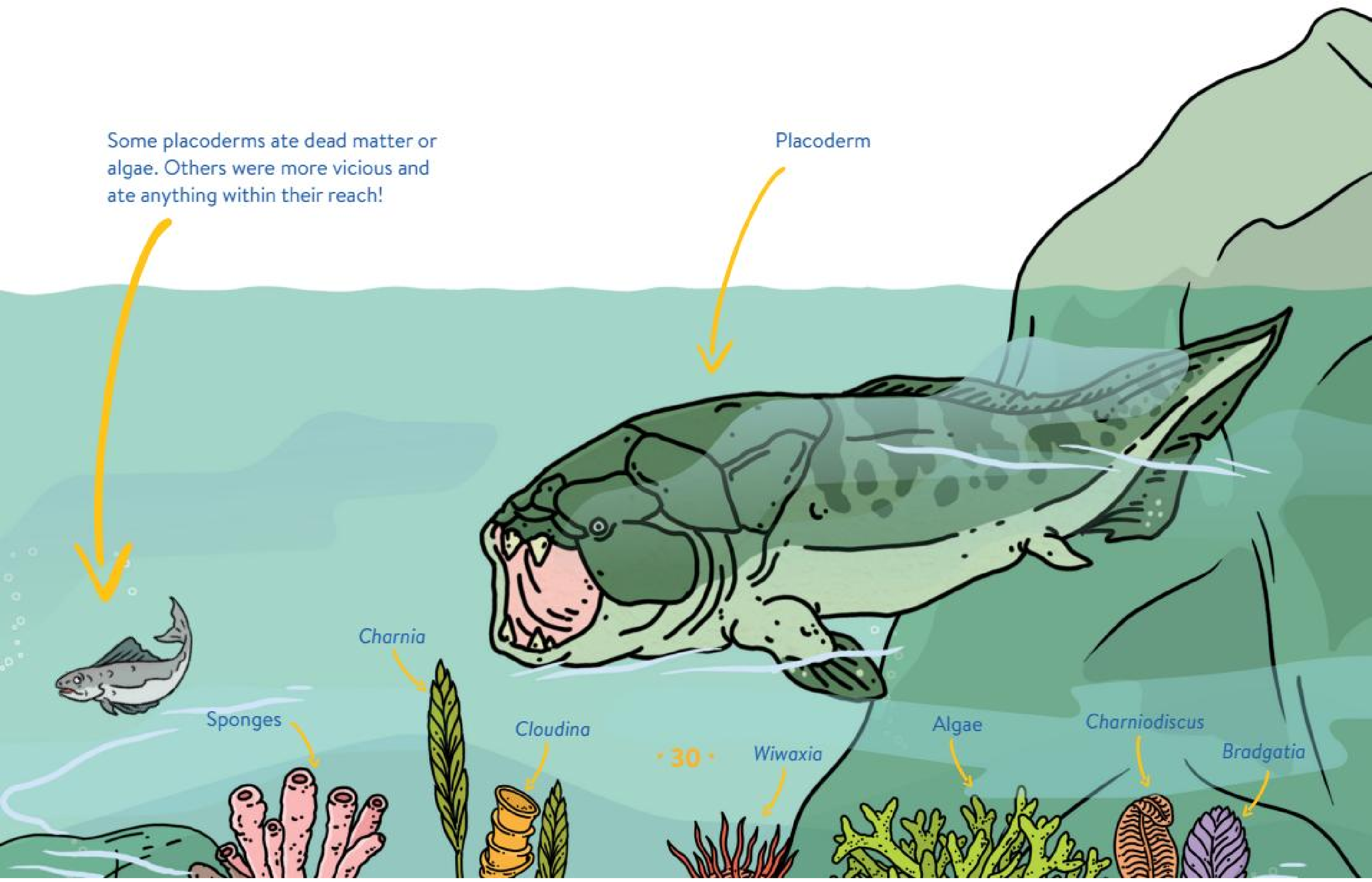
At first glance, sea squirts seem similar to sponges. But sea squirts have babies that swim about like tadpoles. They push themselves through the water with a special tail containing an

Sea squirts



early kind of backbone called a notochord. These creatures are still around today, but they first appeared in the Cambrian period. And sea squirts are thought to be distant ancestors of all animals with backbones – a group called vertebrates. Vertebrates include fish, amphibians, reptiles, birds and mammals. Since humans are mammals, baby sea squirts are super important in our story. Some experts think they should go down in prehistory as the great great great great...grandparents of human beings!

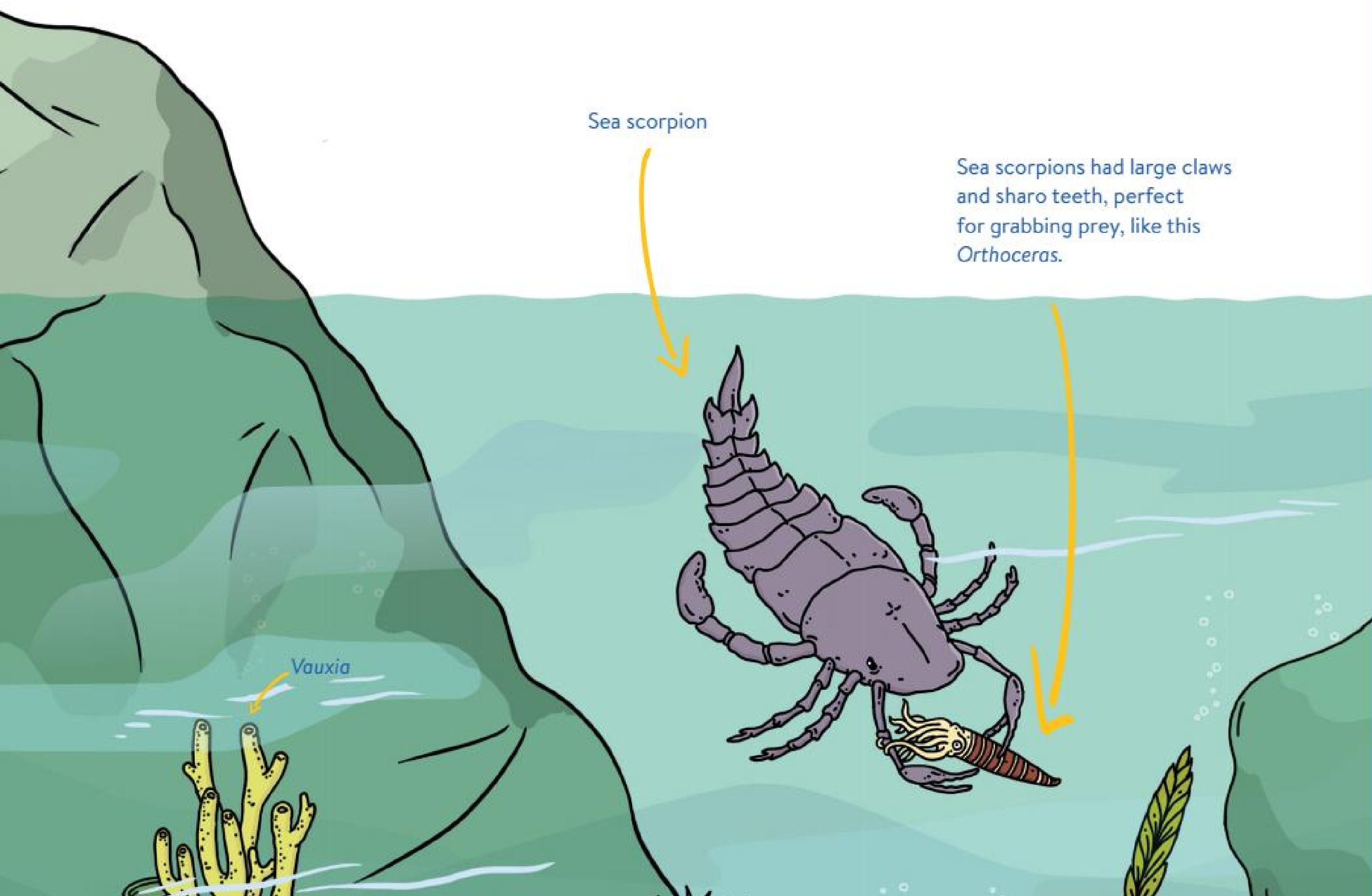
Among the most fearsome creatures of the Silurian and Devonian seas was the now-extinct placoderm. It was a giant fish that had jaws and teeth. Heavy armour plating covered its head and throat. Its body had thick scales, and some had fins covered in armour-plated tubes. These were nature's first war machines, built like a tank. A placoderm could grow up to ten metres long and



weigh over four tonnes. If it were alive today, it could easily snap a shark in two with a single bite.

You wouldn't want to bump into a sea scorpion. It had a long spiked tail that may have been equipped with a deadly venomous sting. This creature could grow to more than two metres long, making it one of the largest underwater creatures of its day. Sea scorpions appeared during the Ordovician period and died out along with many other species in what's called the Permian Mass Extinction, 252 million years ago.

It's been about 4.2 billion years since the Earth was born and about 2 billion years since the first life stirred near volcanic vents on the ocean floor. Our ancestors, and those of all other living things, are now swimming and swaying, hunting and hiding in a very busy ocean. The land, not so much. Mostly it was raining.



Chapter 2

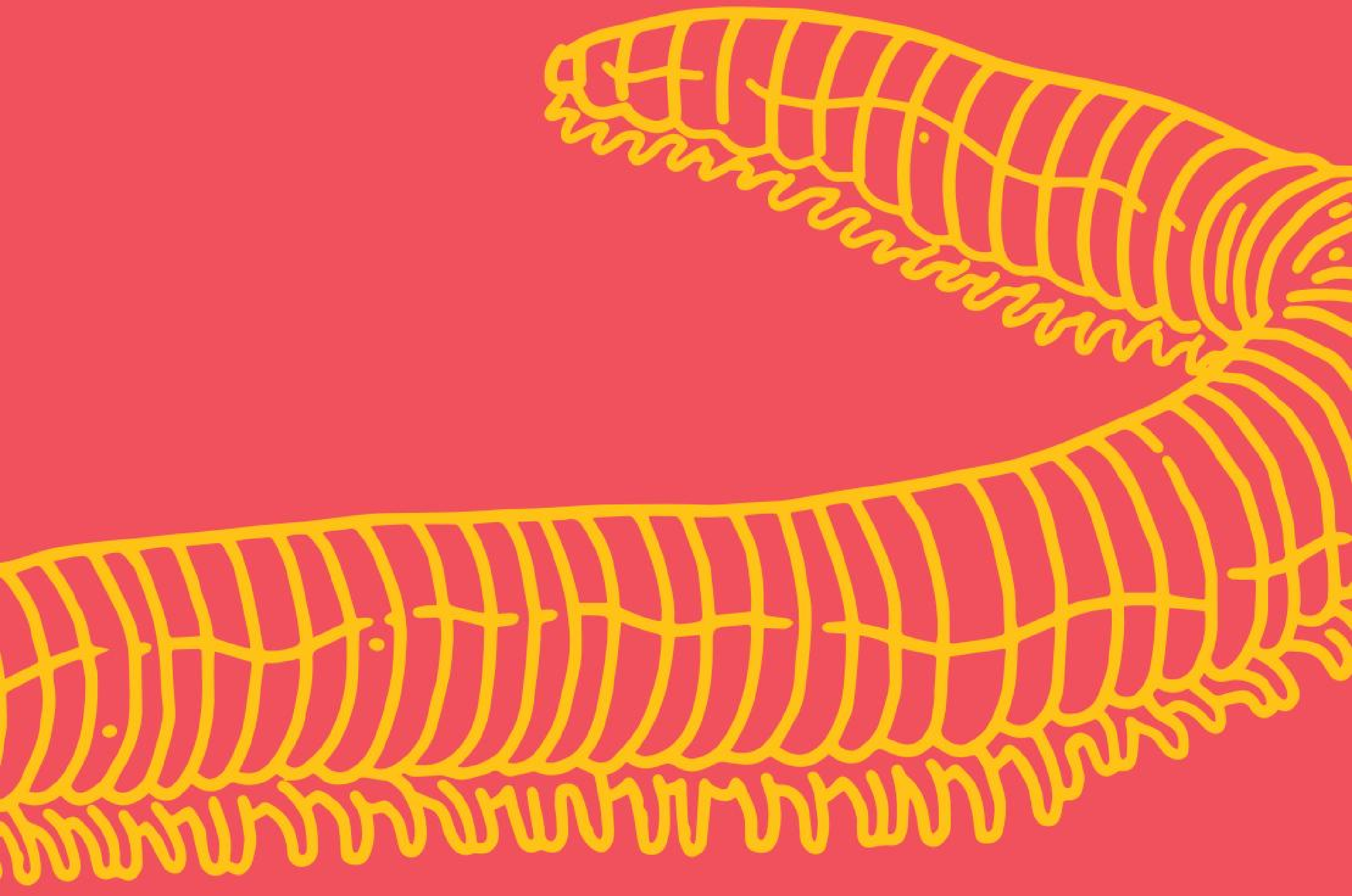
LAND AHOY!

450 million–250 million years ago

Creatures wriggle out of the seas and forests cover the land

Timeline

- **450 million years ago** Primitive plants living on land by the water's edge
- **420 million years ago** First plants with stems and roots develop
- **420 million years ago** Millipedes wriggle out of the seas
- **400 million years ago** Fungi help plants live far away from the water's edge
- **375 million years ago** Amphibians adapt to life on land
- **360 million years ago** Plants develop seeds



360 million years ago
The Earth's land fills up with trees

350 million years ago
Oxygen levels rise as some insects take to the skies

312 million years ago
Reptiles develop eggs with shells

280 million years ago
Dimetrodon uses the sail on its back to warm itself up

250 million years ago
Life suffers its worst-ever brush with death

It was raining. It had rained the day before, too. And the day before that. For millions of years, while life swarmed the seas, rain hammered the land. There was nothing to see except lifeless rock and mud.

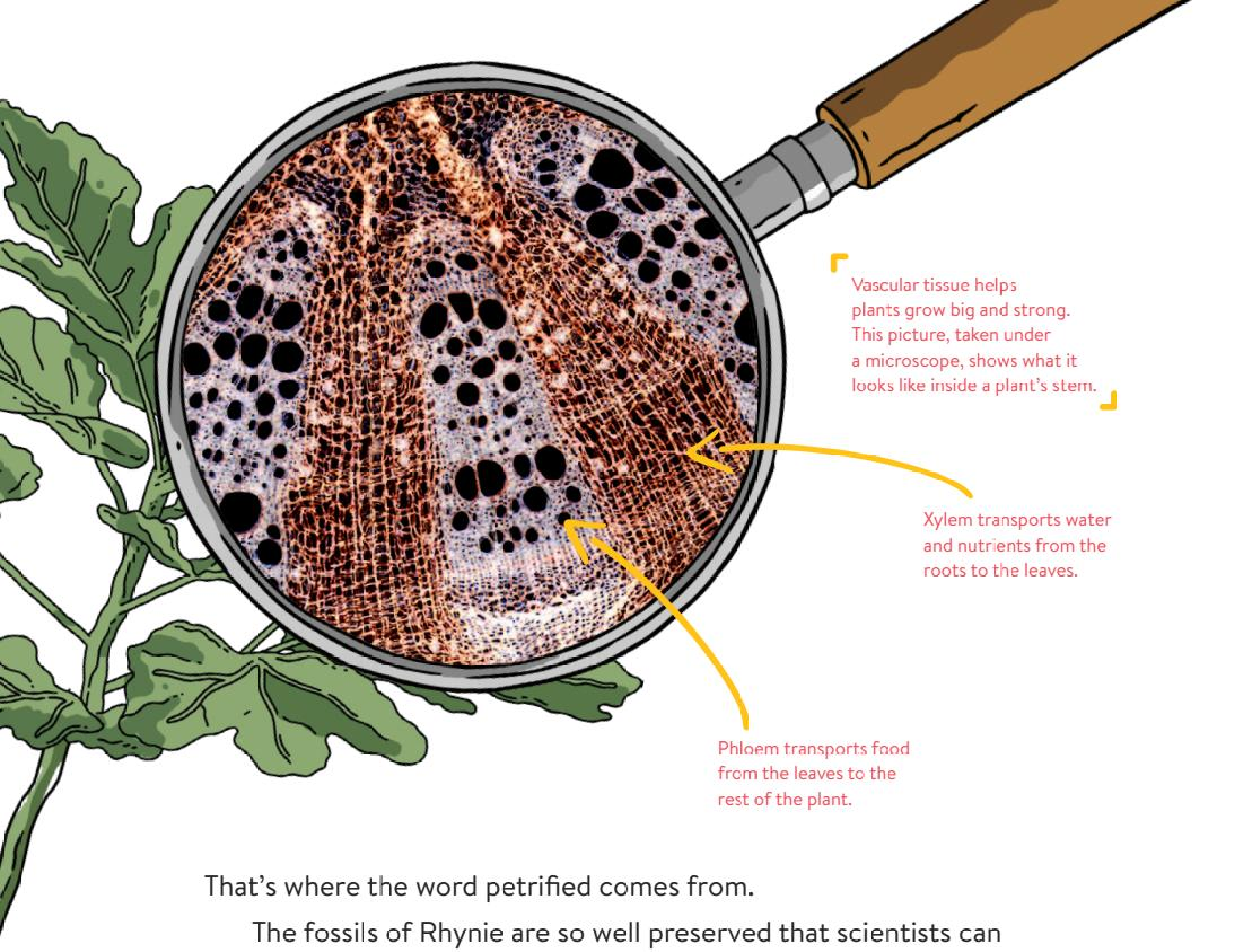
Then, about 470 million years ago, a little green appeared. The first land plants were growing near the water's edge. These were squidgy liverworts and mosses. They had evolved from green algae, a sea plant still around today. Like all plants, these little weeds used photosynthesis to make the energy they needed.

Next came a new type of plant that could grow much taller. These new plants had a system of transport tubes to carry food and water from the ground to the tops of their bodies, sort of like the way we transport blood around our body in our blood vessels. We call these vascular plants.

The first vascular plants were a few centimetres high, with thick stems. We know about them from an accidental discovery made in 1912 by William Mackie, a Scottish doctor, when he was out surveying near the village of Rhynie. Quite by chance he spotted some curious looking fossils in an old stone wall.

You see, it turns out that about 400 million years ago Rhynie was a steaming cauldron. There were boiling-hot pools of bubbling mud. Every so often a giant geyser would spout out a huge fountain of scorching water onto nearby plants. When the water landed on the plants, minerals in it cooled and turned them into stone. When this happens it is call petrification.

An artist's impression of early vascular plants (*Rhynia*) and larger organisms (*Prototaxites*) growing around 420 to 395 million years ago. The *Rhynia* plants were up to 20 cm tall, and the *Prototaxites* trunks rose to 8 metres tall.



That's where the word petrified comes from.

The fossils of Rhynie are so well preserved that scientists can see exactly what these ancient plants were made of and how they worked. It is clear that they contained a chemical called lignin. Lignin toughens the walls of plant cells. It makes the walls waterproof so the tubes inside the plant can carry water up to the top of a high tree. It's like having plastic tubing instead of tubing made from paper.

Having lignin in their cells makes trees woody and keeps them standing up. But it took about 40 million years for these small vascular plants to evolve into proper trees.

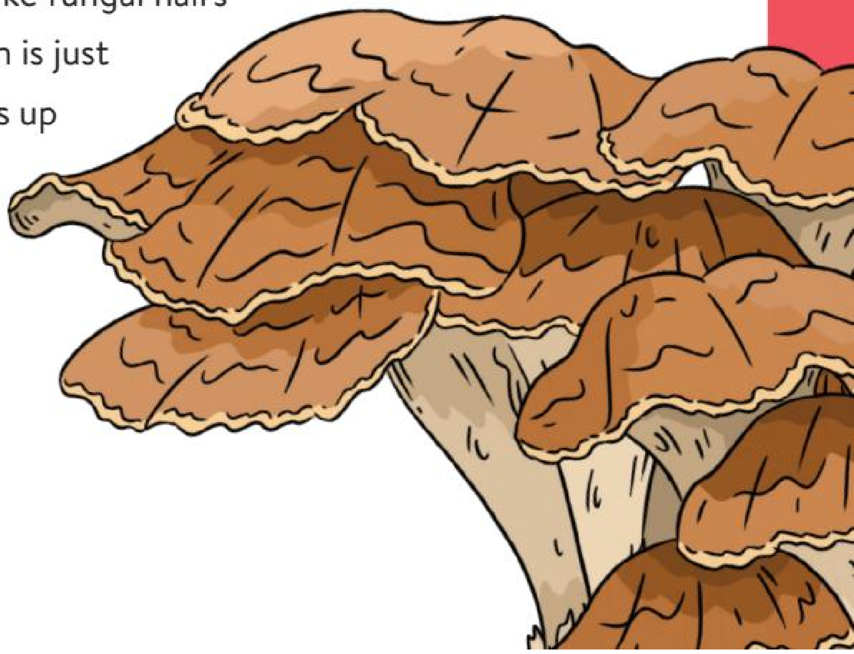
They never could have made it to these heights were it not for another group of living things called fungi.

Do you like mushrooms? I have to say they don't score very high on my list of tasty snacks. But researching and writing this book has turned me into a big mushroom fan. That's because without fungi (the giant group, or kingdom, of living things to which mushrooms belong) the world would be an impossible, disgusting, horrific place.

We don't know much about the origin of fungi. We don't even know if they started in the sea or on land. That's because their soft bodies don't leave many fossils behind. But we are pretty sure that fungi were already living on land when plants got there. Since then, fungi have developed into a huge variety of life-forms, from some of the smallest to the largest living things on Earth.

Small fungi are just one cell. The yeast that makes bread rise is one of those. Large fungi are some of the biggest living things on Earth. One fungus in Oregon, USA, is estimated to stretch out underground across four square miles – equivalent to about 1,500 football pitches!

Plants make energy by photosynthesis. But fungi must feed on other organisms just as animals do. Most fungi are made up of an underground network of root-like fungal hairs called mycelium. The mushroom is just the part of the fungus that pops up above ground. The mushroom's job is to spread spores. These tiny seed-like bits of genetic



Fungi can be found just about anywhere. They can grow in the soil, on your body, in food, on trees, on plants and animals, in freshwater and in seawater!

material plant themselves and grow new fungi identical to their single parent.

Fungi are vital for all life on Earth because they eat dead things. Without them the world would be drowning under piles of the dead bodies of plants and animals – not a happy thought. They also make chemicals that help plants grow.

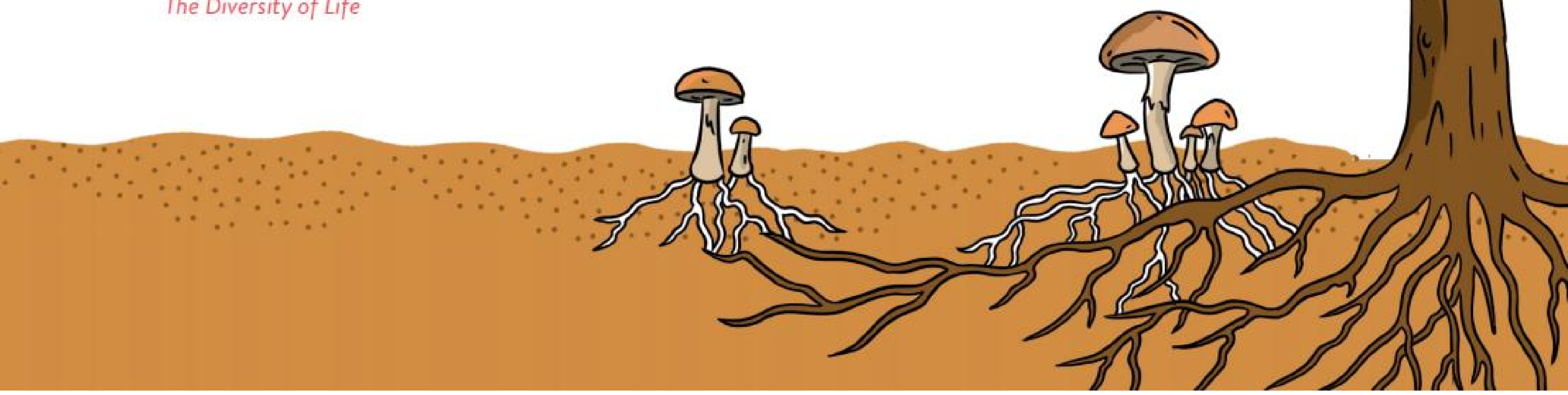
Sometimes nature has a real fondness for teamwork. Big networks of underground hairy fungi pass nutrients and water to the roots of trees. In return trees supply fungi with food through their roots. Thanks to ancient fungi, primitive plant life was able to move further inland, enriching the soil as it went.

Soil (which we often call dirt) is made up of sand, minerals and the remains of once-living things. Plants, insects and fungi all help keep this precious life force working. They turn fallen leaves and rotting trees into nutrients to help new plants grow.

For the last 400 million years fungi, worms and other tiny insects have been digging up the soil. All that digging mixes the soil. Over the course of millions of years, all the soil on Earth is renewed and regenerated. This is called the soil cycle.

> “THE WORLD DEPENDS ON FUNGI, BECAUSE THEY ARE MAJOR PLAYERS IN THE CYCLING OF MATERIALS AND ENERGY AROUND THE WORLD.”
>
> E. O. Wilson, author of *The Diversity of Life*

Without living things, there would be no soil. The Earth would be nothing more than dust and rock, like the surface of the Moon, Mars or Venus.



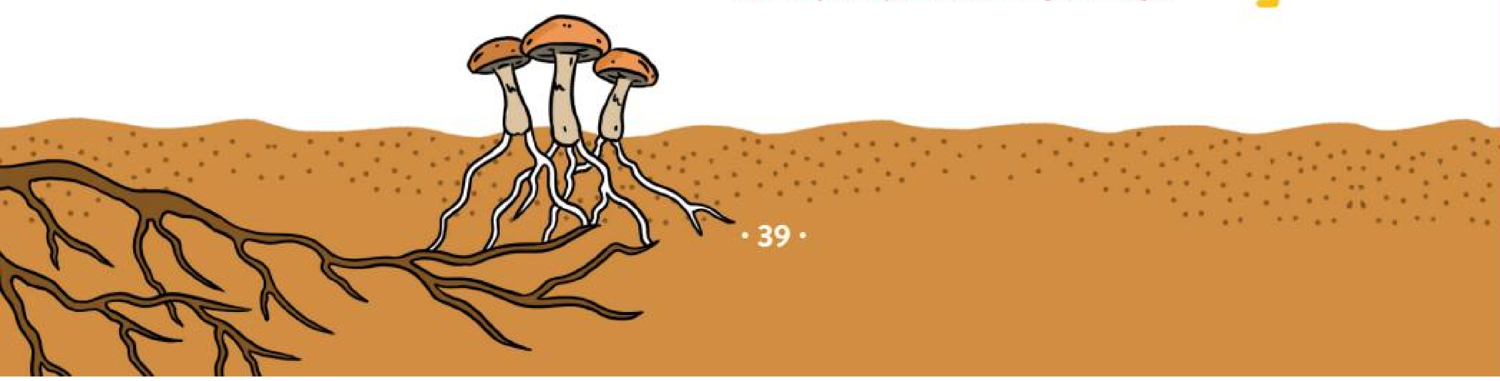
Fungi and plants were not the only organisms to move onto land. A few small crawly creatures emerged at around the same time or maybe even earlier than plants, about 440–420 million years ago.

The first ever land animal might have looked something like a creature with stubby legs that still exists today. It's called a velvet worm. But it's not really a worm. It was probably the ancestor to a big group of animals called arthropods. They include insects, spiders, crabs, lobsters, and a whole lot of other creatures with jointed legs and shells instead of bones. Millipedes were probably the first arthropods.

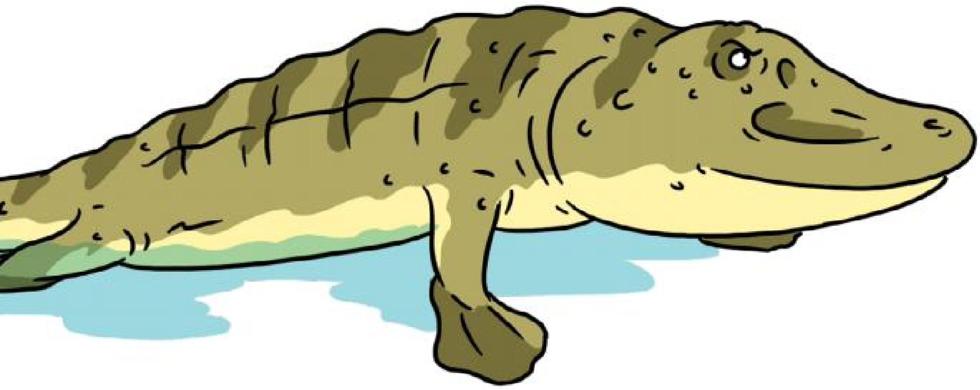
It took about 50 million years before another kind of animal made the move to land. If you were a fish living in the seas back then, life could be over fairly quickly. Giant armoured fish, stinging jellyfish and sea scorpions with deadly tail spikes were just a few of the dangers swimming around. If you were able to get out of the water, you'd have a lot better chance of surviving. After all, the shores were now full of plants and juicy worms to eat.

Fish can't live on the land, though. One problem is breathing oxygen from air instead of water. Another is working out how to move around. Imagine walking on fins instead of legs – it wouldn't be a simple walk in the park.

This is teamwork in action. Through a process called mycorrhiza, fungi and plants mingle together. The fungi supply minerals and nutrients to the plants, and the plants provide the fungi with sugar.



Tiktaalik found a way around this. It used its fins to wade through shallow bogs and to heave its body out of water onto the land. Which means *Tiktaalik* is the first creature ever to have been able to do a press up!



Tiktaalik had wrist bones for lifting its body off the sea floor, lungs for breathing air, and a strong ribcage and neck to help it move and hunt.

Tiktaalik lived about 375 million years ago, when early plants were growing near the shores. Its fossils show how fish-like fins were now being used as the first real arms, shoulders, elbows and wrists.

The reason you and I have wrists and ankles goes all the way back to creatures like *Tiktaalik*. That's because they needed hinged joints to push their bodies up off the ground. Do a press up yourself and you'll see just how important these hinges are!

Tiktaalik is one of the first creatures from a group of animals known as amphibians. *Amphi* in ancient Greek means 'both' and *bios* means 'life'. They live both in the water and on the land. Not only could they walk on land, they could also breathe there. They breathed air through primitive lungs rather than using gills like fish. Equipped with these new features, some amphibians, such as Eryops, became the most dominant creatures on the land. Plus they had staying power. Their descendants include modern frogs and salamanders.

While amphibians were growing into giants, so were plants. As we saw earlier, they had found a way to be strong by making wood. And they'd figured out how to work with fungi to gather food and water in their roots. But to move the water and food up their tubes against the pull of gravity so they could grow tall, they needed a pumping system.

The key to trees' height lies in millions of tiny holes that cover the surfaces of plant leaves. Depending on the weather conditions, plants open or close these little holes, which are called stomata. When it is hot, water in the leaves evaporates through the stomata, making the sap in a tree trunk more concentrated. The water is drawn up through the trunk and into the leaves at the top. It is a process known as transpiration.

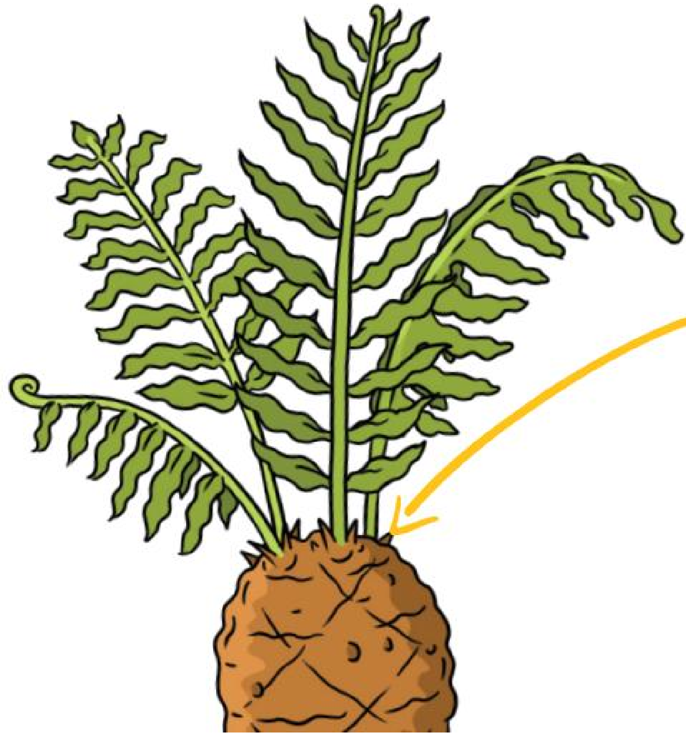
A scanning electron microscope (SEM) allows us to find out lots of information about a surface. The picture in the magnifying glass, taken with a SEM, shows what stomata looks like on the surface of a leaf.

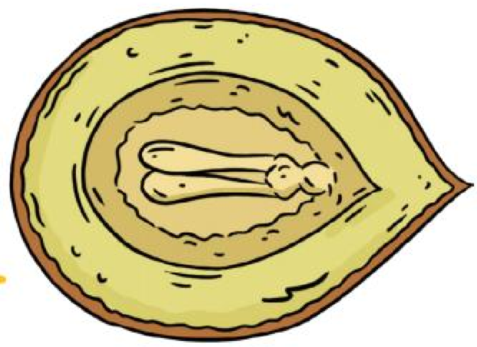
The next step for plants was developing a better way to make baby plants. Early land plants, including trees, created spores just the way fungi do. They released the fungi into the air and let the wind spread them. But spores need warm and wet conditions to grow in. That's fine in damp marshes or bogs but hopeless in dry areas. By about 360 million years ago, some plants developed a new way to reproduce – seeds.

> "THE SEED IS A BRILLIANT DEVICE INVOLVING A WHOLE SERIES OF INNOVATIONS."
>
> Colin Tudge, author of *The Variety of Life*

Seeds are stronger than spores. They have a hard, water-resistant coating called a testa. The protective coat stops seeds getting damaged in the air, on the water, or even inside an animal's guts. Inside the coating, there is the embryo, the part of the seed that will grow into a new plant. And with it is its own private stash of food in the form of sugars, proteins and fats, so the seed has enough nutrients to grow even in a tough environment.

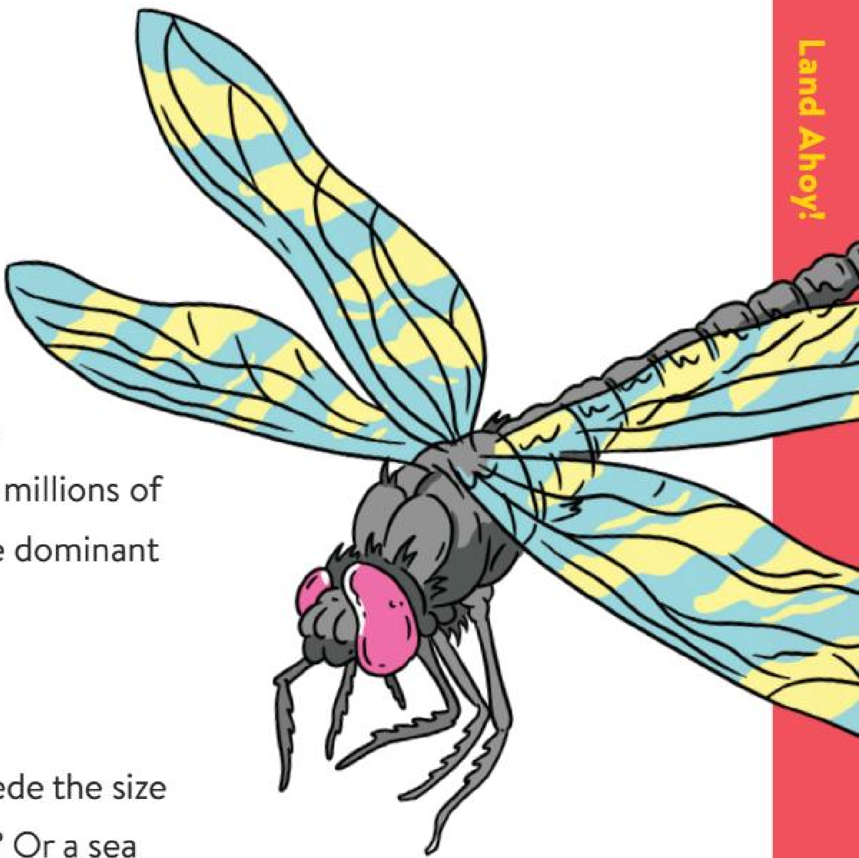
The first seed-bearing trees were called cycads. They look like small palms (although they are not related) and can been traced back





A cycad and one of its seeds. Many of the cycad species still around today can be found in the warm climates of Central America, Australia and Africa.

to about 320 million years ago. About 300 species of cycads are still living today. Like eyesight in trilobites, seeds changed the world entirely. For millions of years they have made plants the dominant form of life on land.



Griffinflies were gigantic. They had a wingspan of around 75 cm. Are you taller or shorter than the wingspan of a griffinfly? They're now extinct, which is probably for the best!

Can you imagine a millipede the size of a person lying down? Or a sea scorpion that is bigger than your outstretched arms? If, like me, you are not so sure that this is a world for you, then be grateful you were not alive 300 million years ago. Welcome to the Carboniferous period.

The seagull-sized ancestors of today's dragonflies were some of the most spectacular of these giant creatures. How they learned to fly is still a mystery. It probably had something to do with the arrival of tall plants and trees. Wouldn't it make sense for an insect to just jump or glide from one tree to another? That way they wouldn't have to climb all the way down and then up again. Experts think something like this is what led the griffinfly to develop its wings.

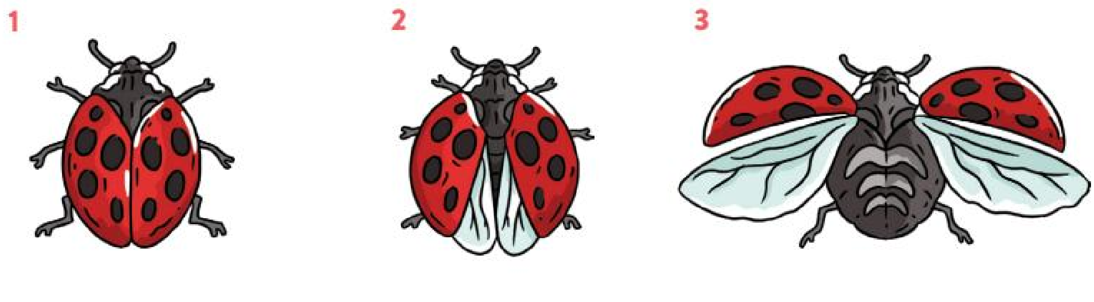
Gradually the griffinflies' little wing flaps grew larger. Finally they could glide, dive and flap their wings. Once they could fly, griffinflies had complete command of the skies. They could feed off smaller creatures as and when they liked. There were no birds back then to

challenge them. They might even have had nearly 360-degree, or all-round, vision the way their descendants do today.

> "THE DRAGONFLY IS AN EXCEPTIONALLY BEAUTIFUL INSECT AND A FIERCE CARNIVORE… [IT] CAN PUT ON A BURST OF SPEED, STOP ON A DIME, HOVER, FLY BACKWARD, AND SWITCH DIRECTION IN A FLASH."
>
> Richard Preston, from 'Flight of the Dragonflies' in *The New Yorker*

We're not sure why these creatures could grow so large. Some scientists think high levels of oxygen in the air (almost twice as much as now) allowed animals to get bigger. Others have shown that oxygen can be poisonous to tiny baby creatures. They think Carboniferous babies had to grow bigger fast so as not to be killed by the oxygen. And a giant insect fossil has been found for a period with much less oxygen. That makes us wonder if oxygen was the cause at all. That's the way it is with science. We come up with ideas called hypotheses that explain the evidence we have. Then if we get new evidence, we sometimes have to change our ideas.

In a world of fierce giants, other creatures simply had to adapt or die. And adapt they did. Smaller insects evolved folding wings, just like those we see in houseflies today. This new kind of wing



Like flies, ladybirds are able to switch very quickly between walking and flying thanks to the mechanism in their wings, which they can easily fold out and collapse.

1

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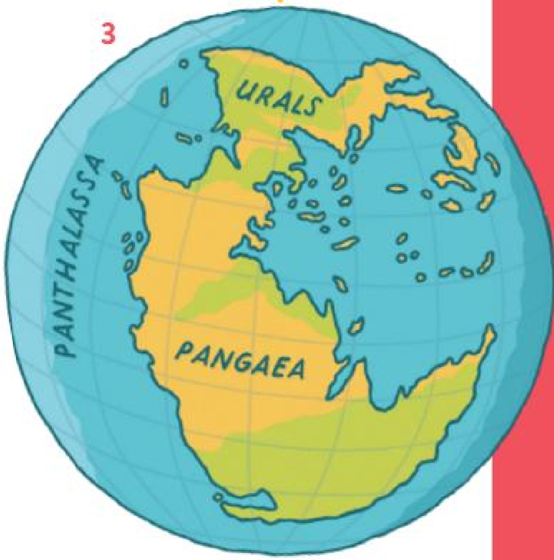
After millions of years of continental drift, Laurasia and Gondwana collided about 250 million years ago. This resulted in the formation of one giant supercontinent, Pangaea.

3



meant that small insects could crawl into narrow spaces. Larger, fixed-winged griffinflies and other predators couldn't reach them there. Flying insects with folding wings are by far the largest group of insects alive today. It goes to show that the folding wing probably counts as another of nature's most successful innovations ever.

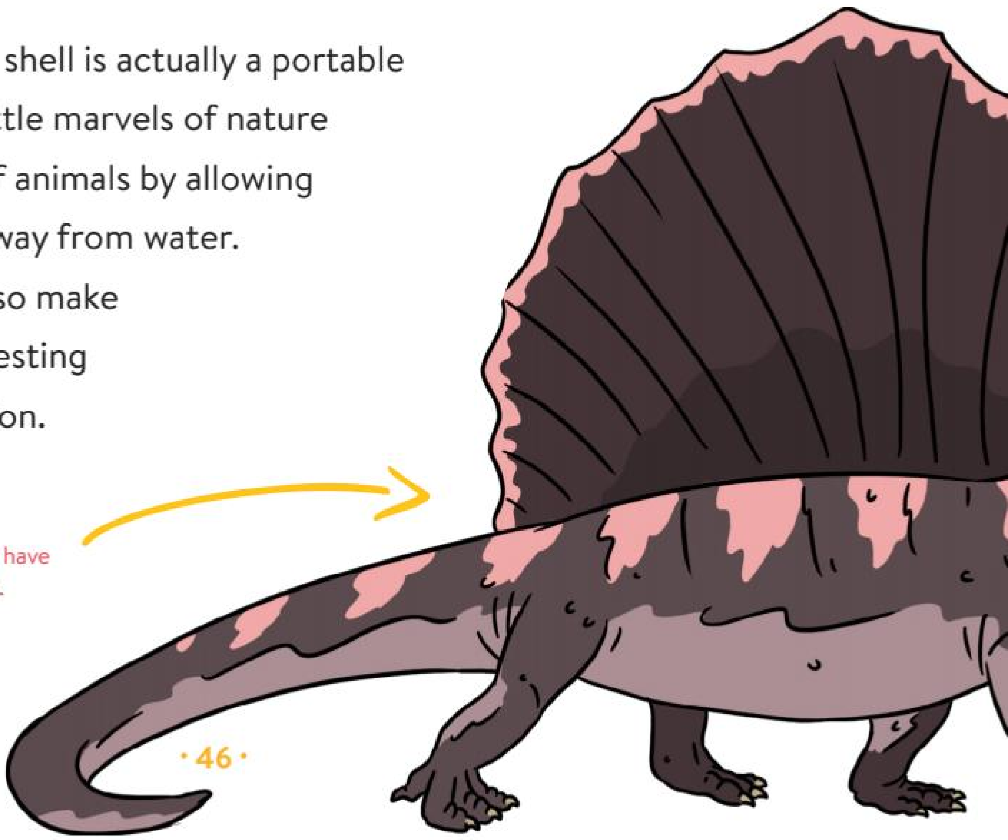
Just about this time, when griffinflies ruled the skies, the world's continents had started colliding together into one giant continent. We call it Pangea (meaning All Earth). This took a while, but even when it started, having just one continent made the climate warmer and drier. So the ponds and streams and puddles where amphibians laid their eggs probably started to dry up. More animals

Squishy eggs, like this frog spawn, let water flow in and out. That's fine for laying eggs in the wet, but they're no good on dry land.

had to compete for less water. As usual when the environment changes a lot, animals changed with it.

Amphibian eggs are squishy, with a covering that lets water in and out. That's the best way when you lay your eggs in the wet. But as the land dried out, some amphibians began to lay a new kind of egg, one a little like a plant seed, with all the water and nutrients a baby creature needs contained inside a leathery, soft or hard shell. Armed with these new eggs with shells, creatures could press-up their way inland as far as they liked. They could lay the egg right on dry land, and after a few weeks, hey presto! Out hatches a little creature. We call these new creatures reptiles.

So an egg with a shell is actually a portable puddle. And these little marvels of nature changed the story of animals by allowing them to give birth away from water. You may find they also make for some quite interesting breakfast conversation.



Dimetrodon's sail-like back may have helped it regulate temperature.

The earliest known reptile was called *Hylonomus*. This 20-centimetre-long, lizard-like creature lived in the Carboniferous period. It ate millipedes and small insects. And it was food for large amphibians and giant griffinflies. Fast forward a few million years and reptiles ruled the land.

One very cool example is *Dimetrodon*. Growing up to three metres long, this lumbering giant walked on four legs and had a long swaggering tail. *Dimetrodon* was the largest meat eater of its time. It had a peculiar sail on its back. Some scientists think it may have been used to heat up its body and blood in the early-morning sunlight. It could then have helped to release heat and cool *Dimetrodon* down in the heat of the day.

Creatures like *Dimetrodon* roamed the land for about 60 million years. But their time came to a sudden end when life suffered its worst ever brush with death – the Permian Mass Extinction.

That single supercontinent, Pangaea, was now fully formed. When continents crash into each other, one thing is certain. You can expect more and bigger volcanoes to erupt. What's the biggest volcano you can imagine? How about one that spreads lava over an area the size of Western Europe?

“THE REPTILES' SCALY SKIN PREVENTED THEIR BODIES FROM DRYING OUT IN THE SUN, AND THE SHELL AROUND THEIR EGGS ENABLED THEM TO BREED AWAY FROM WATER. SO LIBERATED, THEY SPREAD OVER ALL THE EARTH.”

David Attenborough, author of *Life on Earth*

And then goes on erupting for another million years? That's what experts think happened 250 million years ago in the Siberian Traps, a huge area of volcanic rock in what is now northern Russia.

But that's not all. Do you remember those first teeny lifeforms we met in Chapter 1, the ones that lived deep in the sea and were fed by underwater volcanoes? These tiny lifeforms are called methanogens. That's because they produce a substance called methane.

Volcanic activity may not have been the only reason for the Permian Mass Extinction occurring 250 million years ago. It is likely that a meteorite strike in the Antarctica added to the drama.

Methane is one of the greenhouse gases that can cause global warming. Another important greenhouse gas is carbon dioxide. As we saw earlier, carbon dioxide is very important to life on earth because plants need it to live. Still, you can have too much of a good thing. Volcanoes throw lots of carbon dioxide into the air. Experts think that at the end of the Permian period, these two gases combined. There was the carbon dioxide from exploding volcanoes. And there was the methane made by methanogens. Together they warmed the Earth's climate until it was too hot for most lifeforms to survive. Nine out of ten species of plants and animals went extinct.

The event is called the Permian Mass Extinction. It was as if life on Earth had been struck down by a killer fever. But this fever lasted for 80,000 years!

The Bardarbunga volcano in present-day Iceland. The Siberian traps might have looked something like this when they were active

Chapter 3

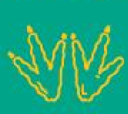
DINOSAURS!

220 million–7 million years ago

Terrible lizards and what came after

Timeline

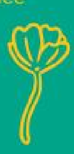
220 million years ago
The age of the dinosaurs begins



220 million years ago
Termites become the world's first insects to live in giant nests

150 million years ago
Some feathered dinosaurs take to the skies, becoming birds

130 million years ago
Plants reproduce using flowers and fruit

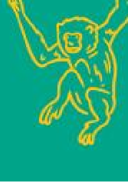


65.5 million years ago
A massive meteorite wipes out all dinosaurs except birds

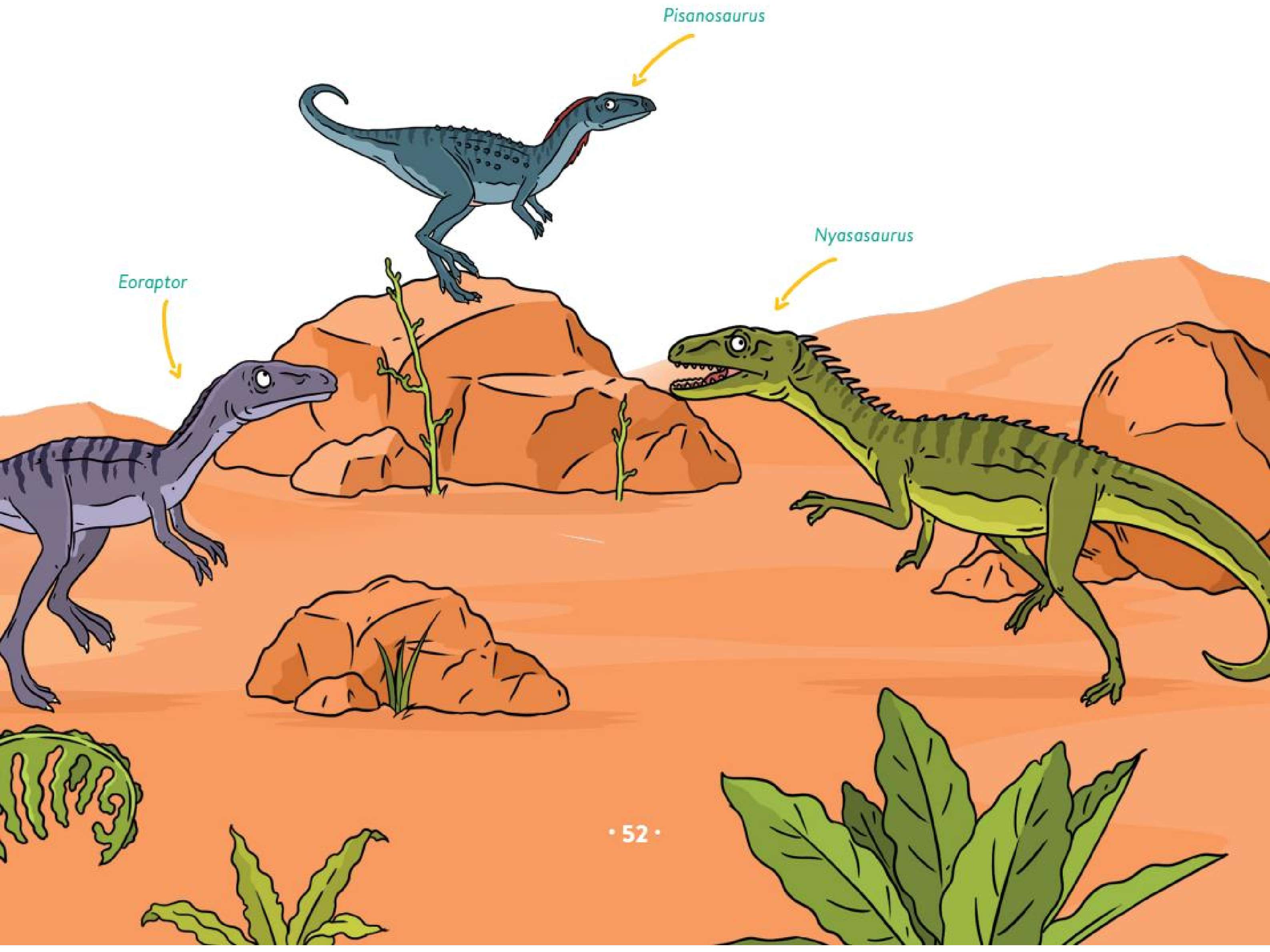
56 million years ago
Mammals and birds take over the world

25 million years ago
Primates spread to the Americas and Asia

11 million years ago
Apes emerge in Asia and travel back to Africa



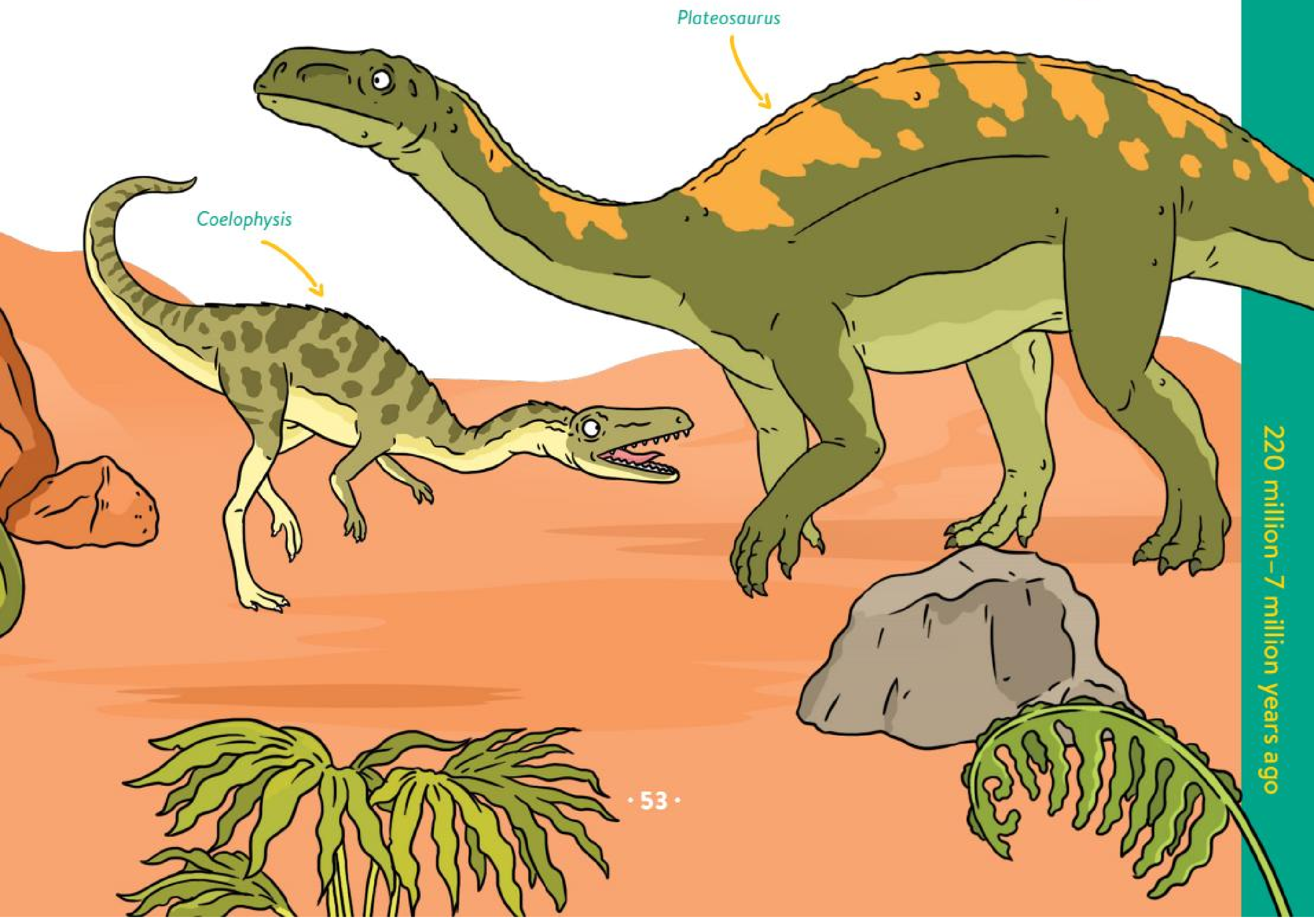
Very few reptiles survived the Permian mass extinction. But one of the ones that did is very important to us. *Lystrosaurus* is a step between reptiles and mammals. If it hadn't survived, some experts think mammals may never have evolved at all. Humans are mammals. So we must be thankful this possible distant ancestor of ours made it, even if it did look like a cross between a lizard and a pig. Then, out of the disaster came a completely new generation of reptiles. These were the most fearsome creatures ever to tread the Earth: Dinosaurs!



Fossils of more than 500 different types of dinosaur have been found so far, although nearly 2,000 are thought to have existed. Some walked on two feet, some on four. Some ate plants, some ate animals, some ate both.

Some of the first known dinosaurs were the *Prosauropods*. These were plant eaters that could grow up to ten metres long with small heads and enormously long necks. They usually walked on four legs, but sometimes climbed onto just two when reaching to nibble at the top of a tree.

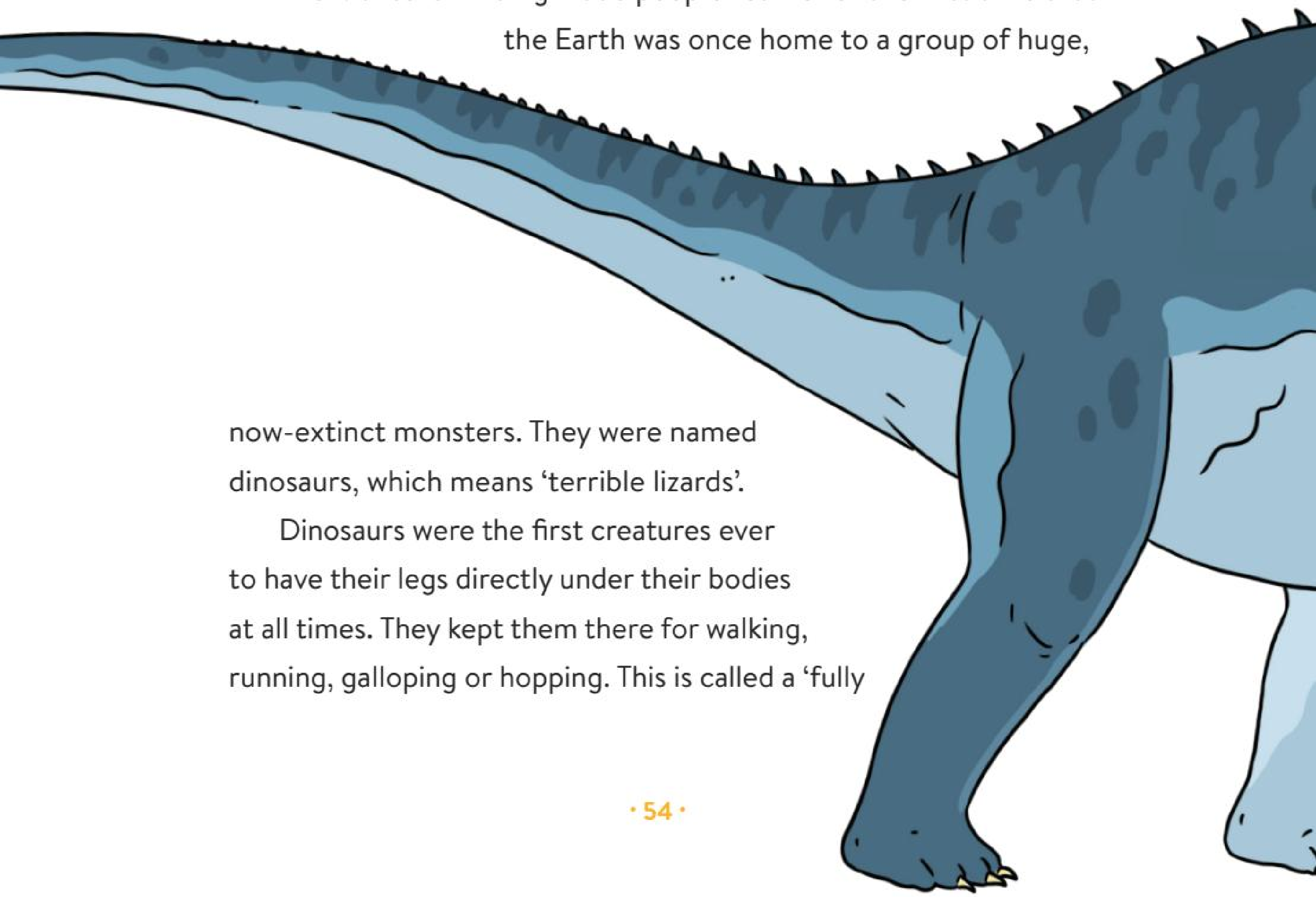
Some of the earliest dinosaurs living 240–200 million years ago in the Triassic Period.



Gideon and Mary Ann Mantell were amateur fossil hunters who lived in Lewes, in East Sussex, England. In 1822 the Mantells found several very large fossilised teeth in a forest near their home. They worked out that the animal they had belonged to must have been at least 18 metres long. That's nearly as long as two double-decker buses!

After years of argument, scientists agreed about the Mantells' teeth (well not theirs, but the ones they found). They decided the teeth must belong to a new type of creature that had never been known before. They called it the *Iguanodon* because they thought it would have looked like a much larger version of a modern iguana.

The Mantells' finding made people realize for the first time that the Earth was once home to a group of huge,

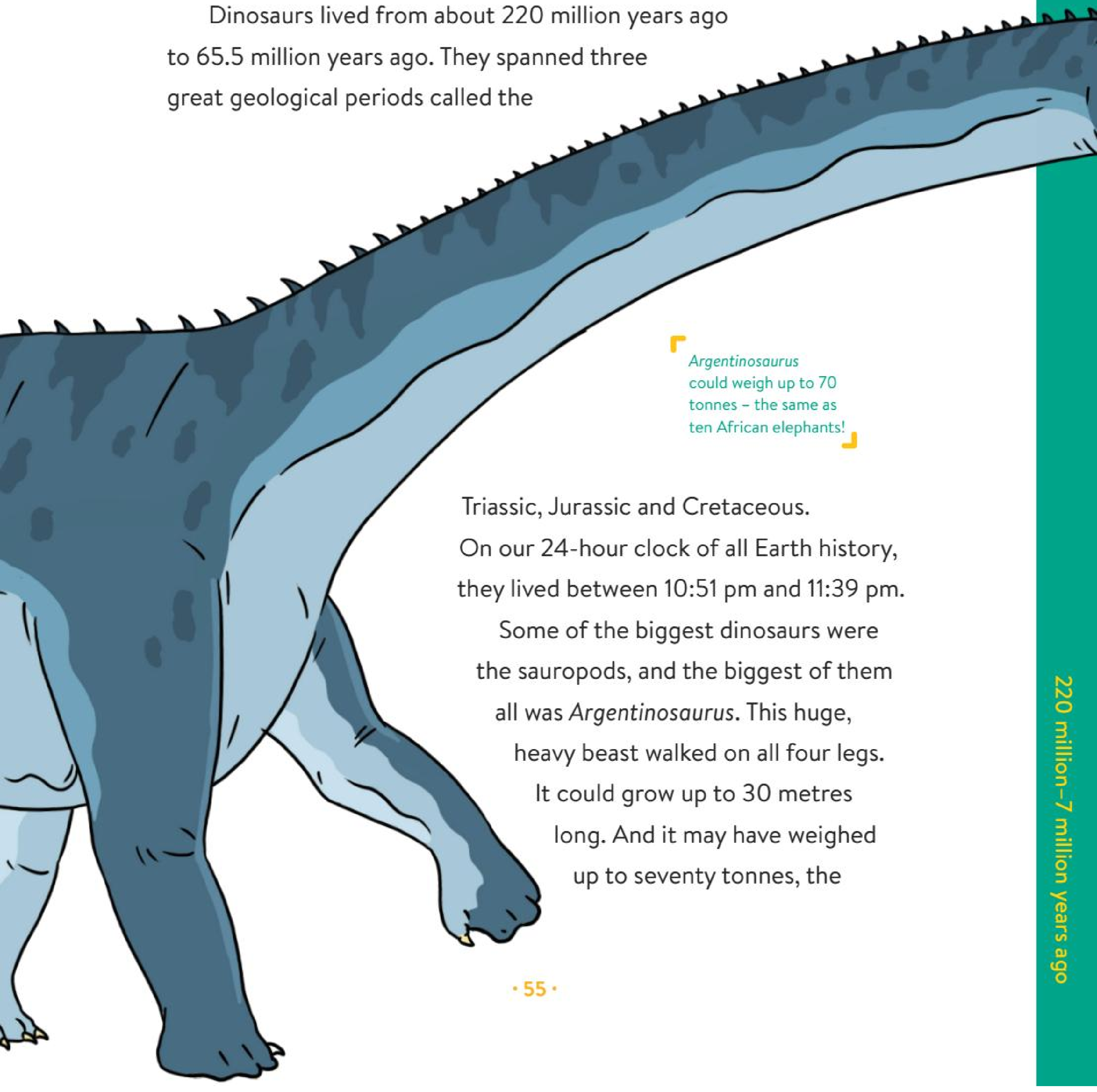


now-extinct monsters. They were named dinosaurs, which means 'terrible lizards'.

Dinosaurs were the first creatures ever to have their legs directly under their bodies at all times. They kept them there for walking, running, galloping or hopping. This is called a 'fully

improved stance'. Some experts think this was the reason they were so successful. Animals with a fully improved stance can grow bigger, move farther and walk faster than other living creatures. It's something that dinosaurs and mammals share.

Dinosaurs lived from about 220 million years ago to 65.5 million years ago. They spanned three great geological periods called the



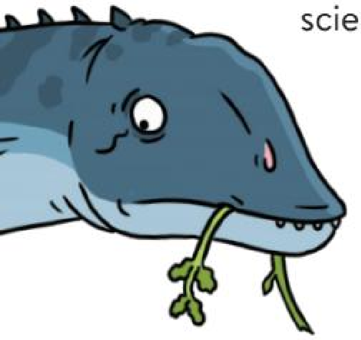
Argentinosaurus could weigh up to 70 tonnes – the same as ten African elephants!

Triassic, Jurassic and Cretaceous. On our 24-hour clock of all Earth history, they lived between 10:51 pm and 11:39 pm.

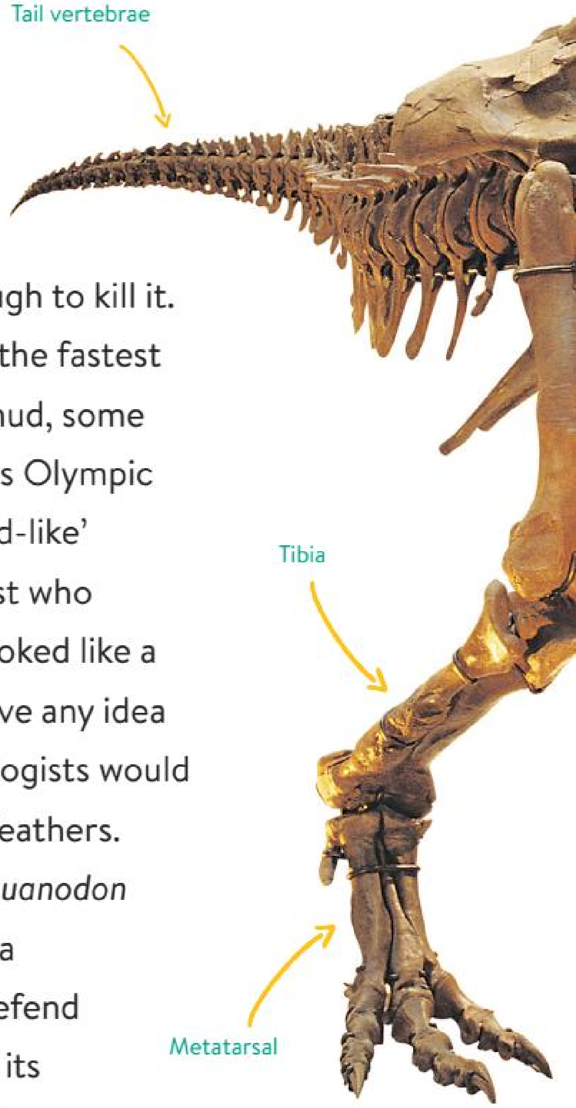
Some of the biggest dinosaurs were the sauropods, and the biggest of them all was *Argentinosaurus*. This huge, heavy beast walked on all four legs. It could grow up to 30 metres long. And it may have weighed up to seventy tonnes, the

heaviest animal ever on earth. Its survival strategy was simple. It grew so large that few other creatures were big enough or strong enough to kill it.

Others were fast. *Ornithomimus* was maybe the fastest dinosaur of all. By studying footprints it left in mud, some scientists figured out that it could run as fast as Olympic champion Usain Bolt. Its name means 'bird-like' because O.C. Marsh, the palaeontologist who named it, noticed how much its claws looked like a bird's. And that was in 1890. He didn't have any idea that over 100 years later other palaeontologists would find fossils that show *Ornithomimus* also had feathers.

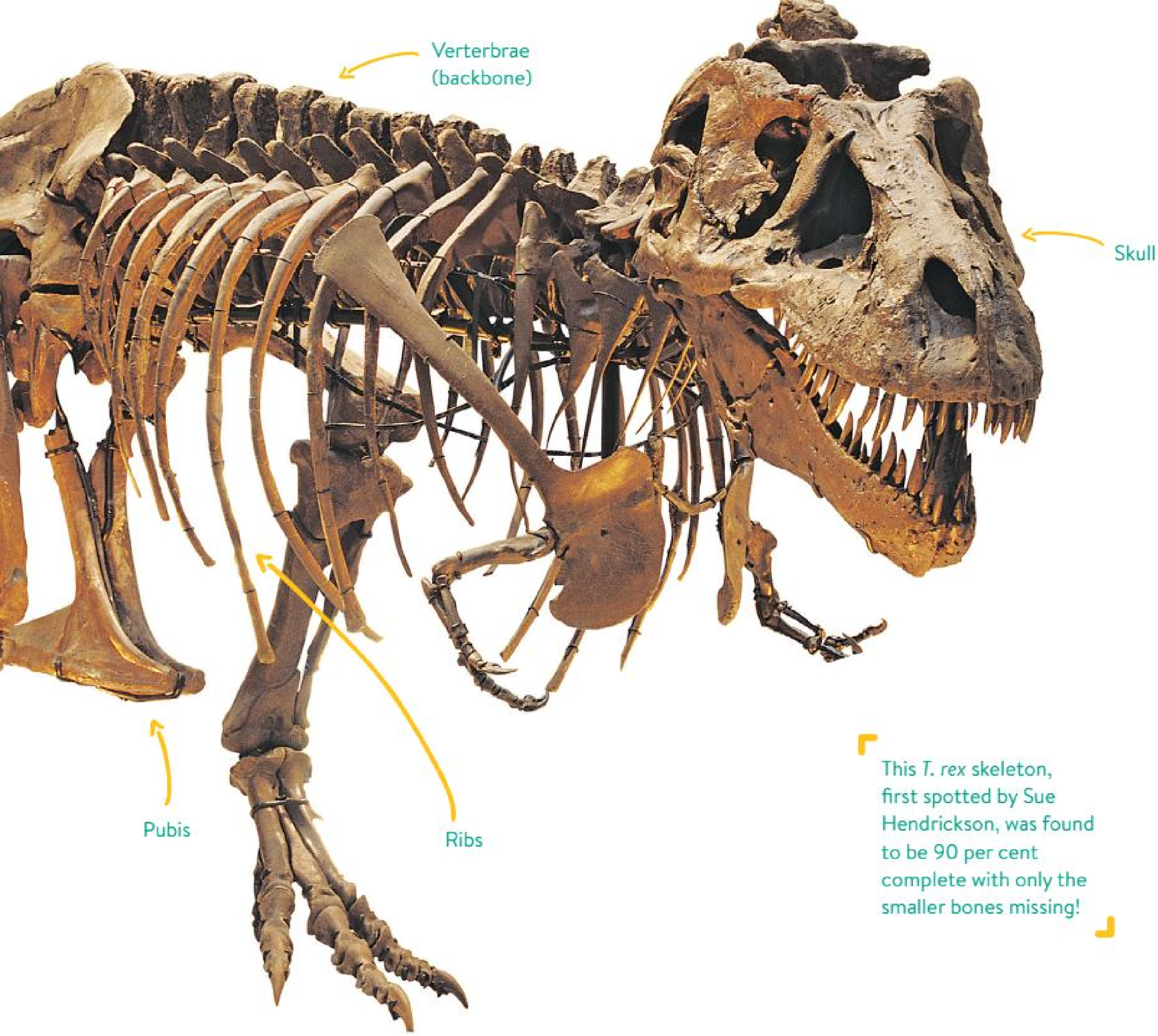


Other dinosaurs had unusual built-in tools. *Iguanodon* was one of those. Its thumb was shaped like into a terrifying dagger. Perhaps it used its thumb to defend itself, standing upright on its hind legs to fend off attackers. But some scientists think *Iguanodon* would just have run from predators and instead used its thumb spike for spearing food.



> "DINOSAURS REPLACE THEIR TEETH THROUGHOUT THEIR LIFE. AND T. REX REPLACED ALL OF THEIR TEETH EVERY YEAR."
>
> Dr Jack Horner, palaeontologist

Of course the dinosaur with the strongest bite is the most famous dinosaur of all, the *Tyrannosaurus rex*, or *T. rex* for short. It lived in what is now western North America. *T. rex* walked on two legs and had a massive skull, balanced by a long, heavy tail. Each of its hands had just two fingers, and its upper arms were quite short compared with its massive legs and tail. At 12 metres



This *T. rex* skeleton, first spotted by Sue Hendrickson, was found to be 90 per cent complete with only the smaller bones missing!

long and weighing more than a modern elephant, this was one big carnivore. It dined off dead carcasses or live prey – possibly both.

The most complete *T. rex* skeleton was found by fossil hunter Sue Hendrickson in August 1990. It measures nearly 4 metres high and over 12 metres long. This famous fossil was named Sue after its discoverer. It is on display in a museum in Chicago, USA.

But not all dinosaurs were big or fast or strong. The smallest one, *Microraptor*, was a four-winged dinosaur the size of a crow. It couldn't fly but probably glided from tree to tree looking for prey.

In 1861 Hermann von Meyer, a German fossil hunter, announced the discovery of what he claimed was the first ever bird. He called

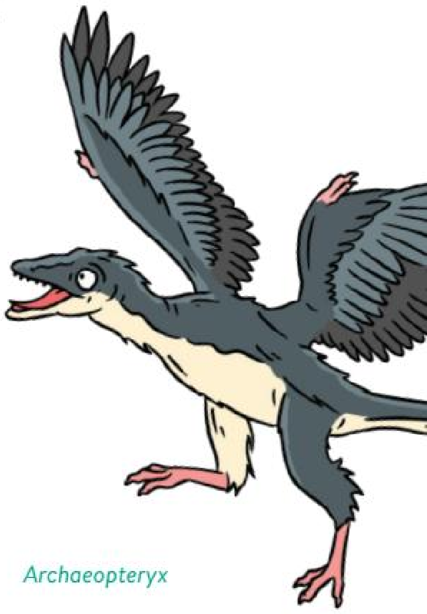
Another bird-like dinosaur with feathers on the back of its head, body and arms was the *Sinornithosaurus millennii*. This fossil, found in China, dates to 139–122 million years ago.

it *Archaeopteryx*. It was about the same size as a modern magpie, and was definitely bird-like. Its feathers were arranged in just the same way as modern birds. It even had bird-like claws on its legs, and a wishbone. Von Meyer's fossil dated back some 150 million years, about the same time the long-necked prosauropods were munching the tops of trees.

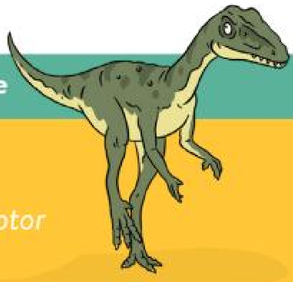
For years experts were baffled as to which creatures birds were descended from. How had they learned to fly? Where did their feathers come from? Knowing about just one prehistoric bird wasn't enough to understand what happened.

Then, in 1995, Chinese scientists announced that fossil hunter Li Yumin had found a fossil that showed some dinosaurs had feathers. *Sinosauropteryx* caused a sensation. This was a 1.5-metre-long two-legged creature with the jaws and flattened teeth of meat-eating dinosaurs. It had clawed fingers, and its legs showed it must have been a fast runner.

The puzzle of where birds came from had at last been solved. Feathers first appeared on some dinosaurs. They were probably to help keep their bodies warm. This is a big deal because it means they were warm-blooded like birds and mammals. Then later, some feathers evolved into the kind that helps birds fly. Many scientists think that all theropods (smart, fast



Archaeopteryx

Date	Name		Characteristics
230 million years ago	*Eoraptor*		Five digits at the end of their limbs. Birds today have three digits in each of their wings.
220 million years ago	*Coelophysis*		Wishbone. Birds today have a wishbone – two collarbones stuck together in a forked shape.
120 million years ago	*Oviraptorosaur*		Feathers and nest-brooding. Oviraptor was discovered alongside some fossilised eggs. People think it was probably brooding over its own eggs like a chicken.
today	Chicken		Feathers, talons, beak, wish bone. Chickens today are farmed worldwide for meat and eggs.

We don't know exactly how birds evolved from dinosaurs. But here are some examples of species and their characteristics that hint at the way that today's birds emerged.

predators including *Velociraptor* and *T. rex*) had feathers, especially when they were young. So what's the difference between birds and dinosaurs? Well, not much.

Don't panic as you read this, but this all means that actually dinosaurs are alive and well in the world we live in today. At least the ones that could *fly* are still alive. It's just that we call them birds!

While dinosaurs ruled the land, two other types of animals were in charge in the seas and the skies. Sea monsters that looked like giant sharks, underwater crocodiles, and nightmarish long-

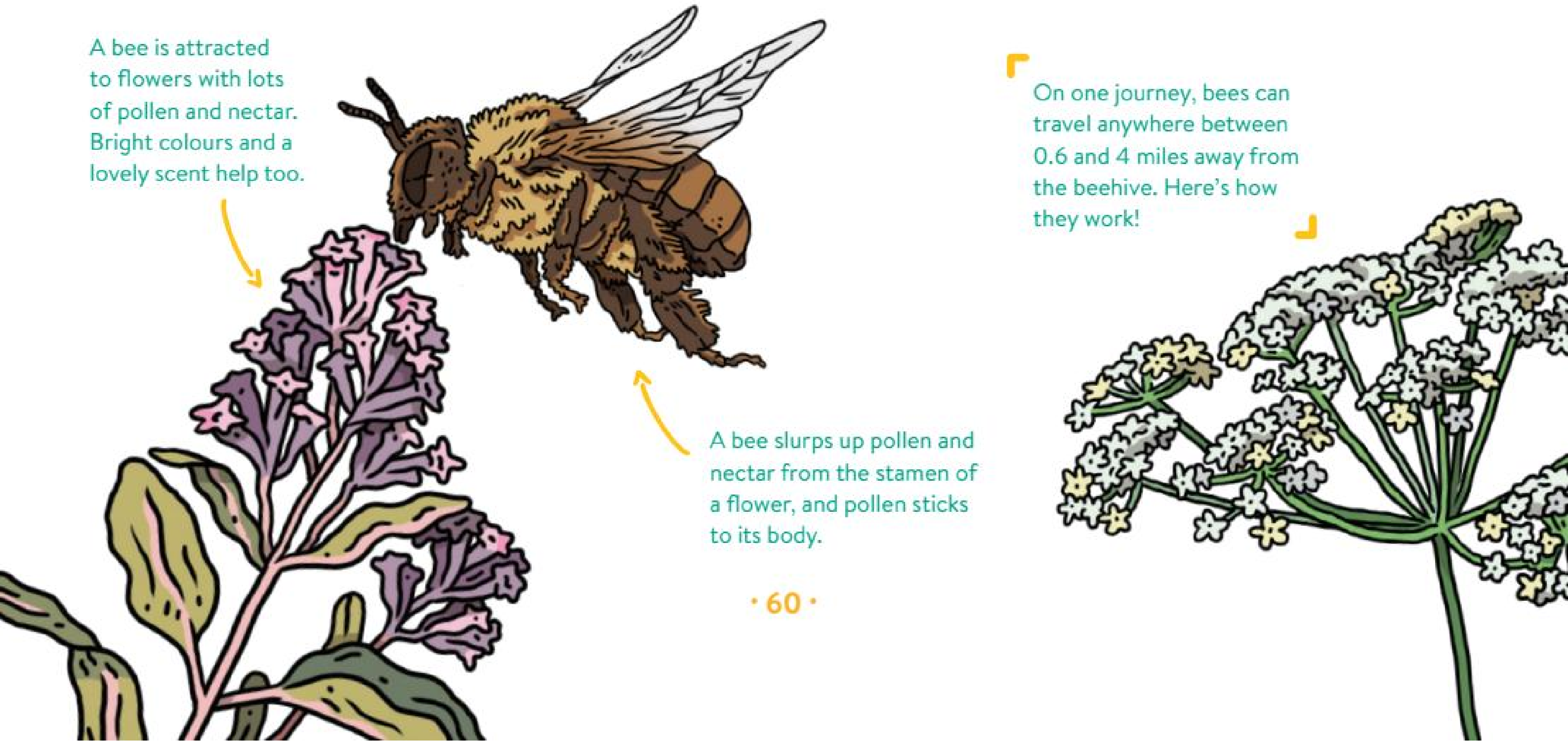
necked creatures prowled the seas gobbling up squid and fish. And in the skies, the pterosaurs swooped and glided, including giant *Quezylcoatlus*, with a wingspan of 12 metres!

Dinosaur times were pretty exciting, but they were missing one thing we now take for granted – flowers! Flowering plants are by far the most successful plants alive today. But for over 300 million years, none of the plants in the world had flowers.

The oldest flower fossils date back about 130 million years ago. This was the Cretaceous Period, when dinosaurs were at the height of their power.

Flowering plants have since made a massive impact on life on Earth. In fact, more than 75 per cent of all the food that we eat comes from flowering plants. We eat them ourselves in the form of vegetables and grains, and the animals we eat also eat them.

Flowers are brilliant at allowing plants to reproduce more easily. To talk about how, we need to go back to between 1 and 2 billion years ago. At that time, a new form of reproduction started

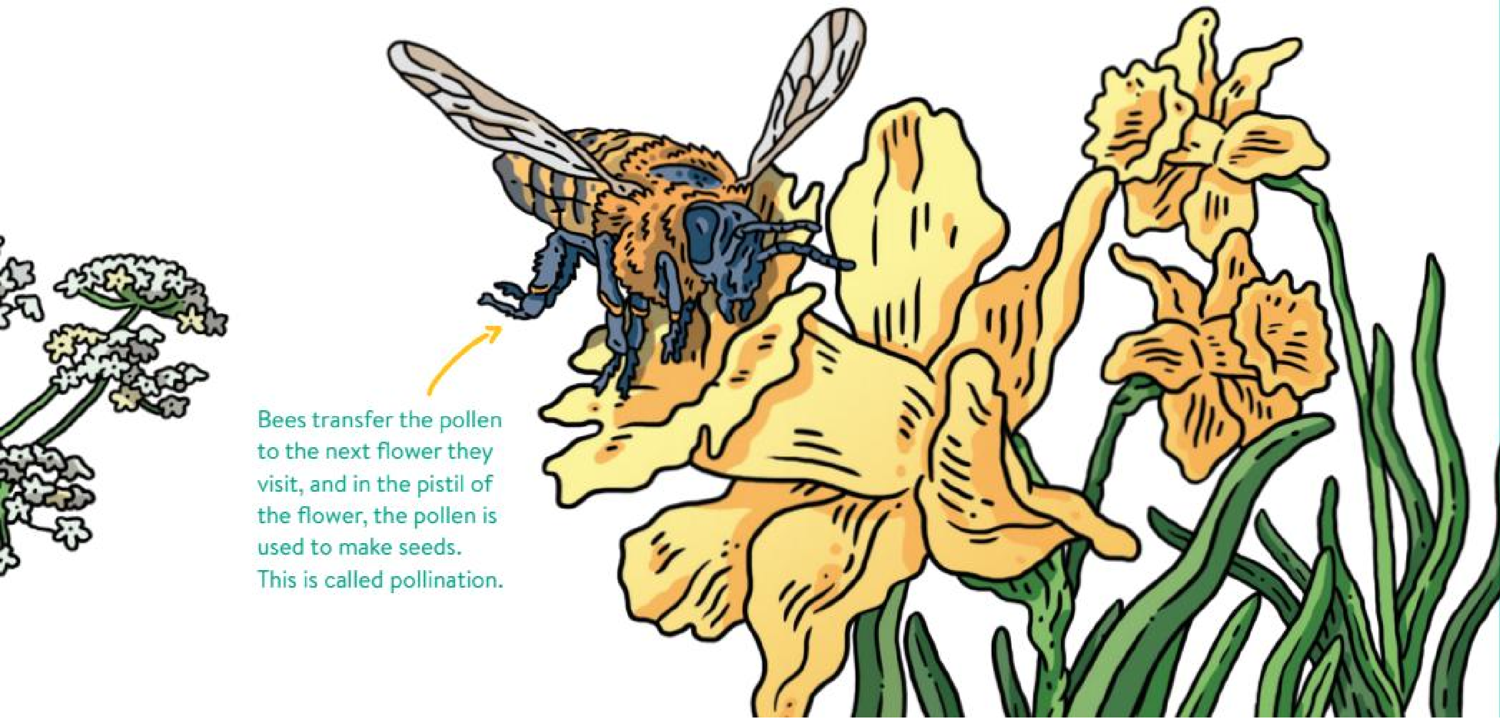


in the ocean. We call it sexual reproduction. Sexual reproduction works by combining DNA from two parents so that the baby has a combination of the parents' genes. That way, the baby is different from either of its parents. It's a great way of making sure all living things are different from each other. In fact, it works so well that almost all lifeforms you see around you now reproduce this way.

But trying to do this when you are a plant is quite tricky. Plants are rooted to the ground. So how on earth can two plants swap cells to make new plants when they cannot move from one place to another?

Flowers are a brilliant solution to the problem. They spread their reproductive cells (called pollen) from one plant to another in many clever ways. Some release them to be carried by the wind. Others attract creatures, such as beetles, bees and moths, that move from place to place. Some even partner with a very particular creature to spread their pollen.

Beetles, bees and moths need flowers just as much as some flowers need beetles, bees and moths. The flowers provide food, in the form of a sugary liquid called nectar, while the insects carry



Bees transfer the pollen to the next flower they visit, and in the pistil of the flower, the pollen is used to make seeds. This is called pollination.

the flowers' pollen from flower to flower. Everyone's a winner! The reason that many flowers are brightly coloured is so they can attract insects. It's like a form of TV advertising, saying, "Hey, look at me, over here! I have a sugary drink and, guess what, it's FREE!"

But plants still have a problem. Their seeds must be spread to avoid young plants growing up too near their parents. It they did, they would end up competing for vital nutrients and water. Some seeds travel on the wind (such as the helicopter-like seeds of a sycamore tree), some by water (a coconut), or some by sticking to an animal's fur (a burr).

But the most interesting method of all is to package seeds inside a tempting, ready-made meal. We call it fruit. And that's the real purpose of all fruit, from strawberries and apples to peaches and even tomatoes! Fruits are nature's ready-made meals designed by flowering plants to tempt animals to eat them and spread their seeds. Later, when they've been digested, the seeds inside are randomly scattered on the ground in the animal's dung. That way they grow far away from where they were eaten in the first place.

Oh! And nothing is better for helping seeds grow that a shot of manure in the form of animal dung. Another great example of teamwork in action.

Helicopter seeds – which are produced by field maple, Norway maple, sycamore and ash trees – spiral through the air, enabling them to travel further so they have plenty of space to grow.

We are now roughly 100 million years from the present day. Let's see, that's about 11:47 on our twenty-four-hour clock of Earth history. Hmm, only 13 minutes to go ... any sign of any humans yet?

Actually, there is a hint of humans in going on, even though it's still millions of years before any sign of our ancestors can be seen wandering across the grassy plains of Africa.

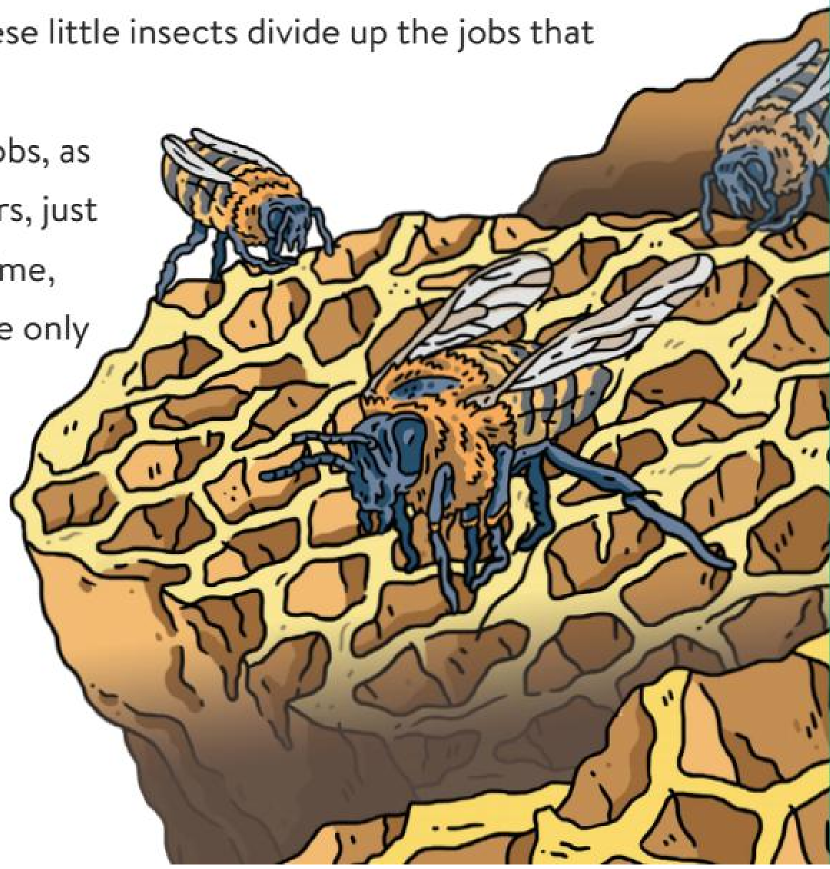
Today, people live in vast towns and cities, some with more than 30 million people. But the idea of millions of the same animal species living close together first appeared long before humans. Enter the first insect 'cities'. These are the giant communities of bees, ants and termites.

> NO LIVING CREATURE, NOT EVEN MAN, HAS ACHIEVED IN THE CENTRE OF HIS SPHERE, WHAT THE BEE HAS ACHIEVED IN HER OWN...
>
> Maurice Materlinck, *The Life of the Bee*

There are about 20,000 different types of bees alive today. Some – especially honeybees – form highly social groups. It's fascinating to see how much alike bee hives and humans cities are.

Honeybees pass on knowledge from one generation to another. They care for their young, and sometimes they even sacrifice their lives for the group. Also these little insects divide up the jobs that need to be done.

People have different jobs, as teachers, nurses and farmers, just to name a few. For a long time, people thought we were the only



At the centre of a beehive lives the queen bee. Drone bees are male and there aren't many of them in each hive. Their job is to mate with the queen bee. Worker bees are female and make up most of the beehive's population. They gather pollen and nectar to make honey.

animals that divided work this way. And we thought it started when the first towns and cities developed a few thousand years ago. But, as any beekeeper will tell you, that is not so. Honeybees do it too. It's a good example of how things we assume happen only in the human world began in the lives of other creatures all over the natural world.

Honeybees also communicate. They talk to each other through the language of dance. When a bee returns to the hive from gathering food, it tells the others where to look for more food by performing a certain type of dance. The 'round dance' means that food is within fifty metres of the hive. The 'waggle dance' provides details about both the distance and the direction of the food. Then there is the 'jerky dance'. This is used by the bees to decide whether to increase or decrease the amount of food gathering they need to do, depending on the hive's overall needs.

Ants belong to the same insect group as honeybees. The oldest fossils of ants' nests date from about 150 million years ago. There are many similarities between ants' nests and

Leafcutter ants are gardeners. They cut plant leaves and carry them back to the colony to feed a special fungus that grows in gardens in their nest. The ants then dine off the fungus when it is ready to eat!

honeybees' hives, but ants do not dance. Instead, they communicate through sound, touch and smells. When an ant finds food it will leave a trail of scent along the ground all the way home, to lead others to its source. It finds the way back by remembering certain landmarks, often using the position of the sun as its guide.

But the prize for the first insects to work out how to live peacefully together in giant groups must go to termites. Fossilised termite nests date back 200 million years. These tiny creatures create some of the biggest insect cities of all. They often live in colonies that number several million. A queen can lay thousands of eggs a day. She gets so large (sometimes up to 10 centimetres long) that she is often unable to move. If she needs more space, a team of worker termites heave her up and push her to a newly built chamber.

Dinosaurs might have been the most successful land animals of their time and insects the most sociable, but there were other creatures around and about as well. Starting about 10 million years after dinosaurs came on the scene, another type of creature was living in the shadows. Mammals were descendants of creatures

related to *Dimetrodon* – the one that developed ways of using the sail on its back to keep its body temperature steady.

Mammals went a lot further controlling their temperatures. The ability to keep your body warm when it's cold outside is called being warm blooded. Because mammals were warm blooded, they could hunt at night and sleep during the day, avoiding the worst predators. They also got smaller than their ancestors. That made it much easier to hide away in the daytime, under rocks or inside a tree.

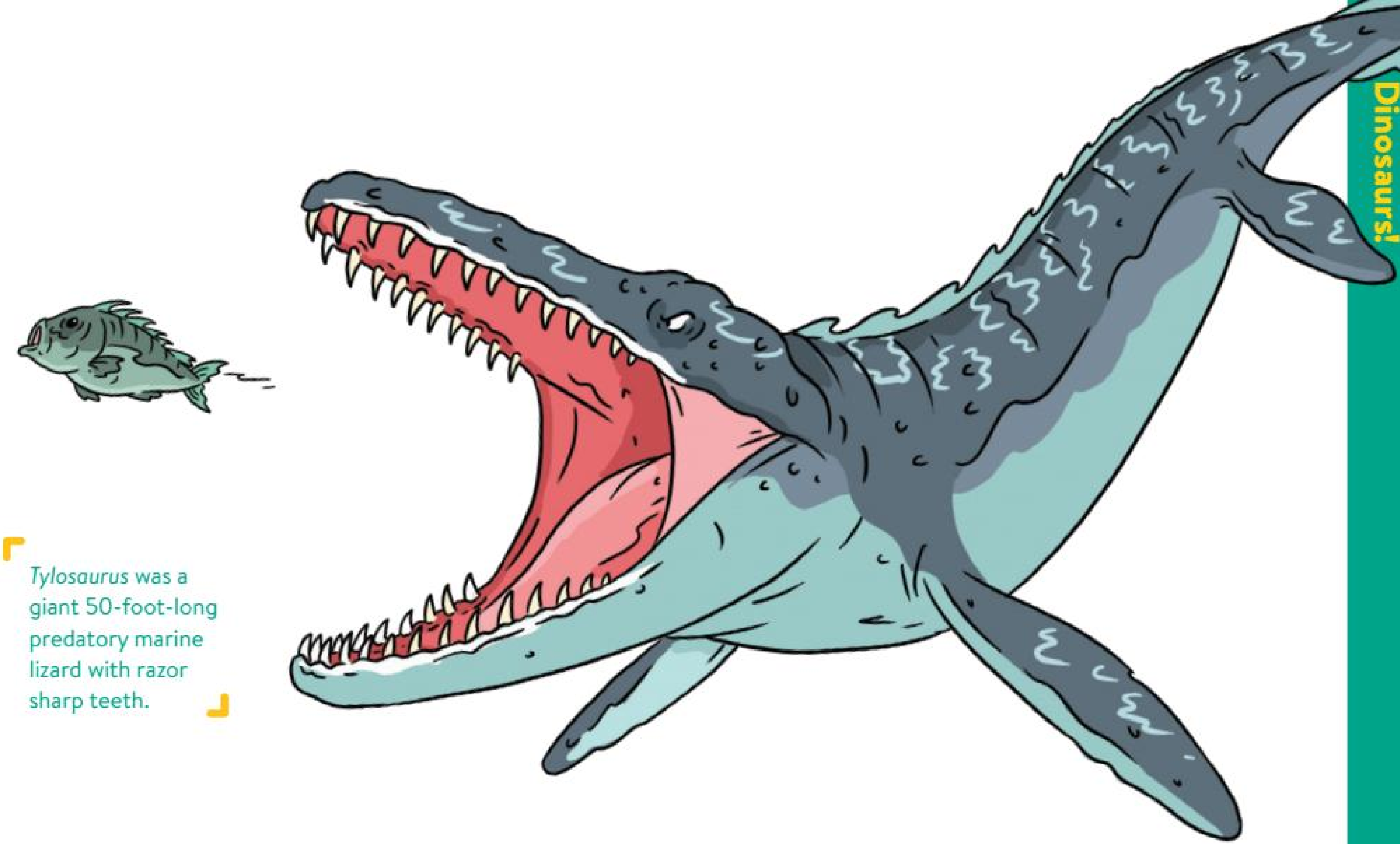
And to help stay warm, mammals grew fur. The reason we have hair on our heads goes all the way back to our rat-like mammal ancestors. They developed fur all over their bodies to keep themselves warm for hunting at night so they could escape attack from the dinosaurs!

But how could they hunt when it was dark?

Many nocturnal animals have eyes with lots of light-sensitive cells called rods in them. Rods help animals like your cat see when there's very little light. And some mammals have eyes that are great at detecting movement. They can see their insect prey darting around even with a tiny bit of light.

Mammals also developed excellent hearing. This allowed them to detect the faintest rustle of a possible meal in leaves and grasses. Much later, a few mammals, such as bats, would develop this amazing hearing even more. They use a system called echolocation. It allows them to create a detailed mental picture of the world around them using sound.

The sabre-toothed squirrel was a shrew-like mammal with fangs.



Tylosaurus was a giant 50-foot-long predatory marine lizard with razor sharp teeth.

Another way mammals became pros at night hunting was by growing the smell-interpreting part of their brains. They then used their brains and their noses to find the yummy food they craved. If you have a cat or dog, you'll know exactly what I mean.

Then it all ended. Dinosaurs had dominated life on land for more than 170 million years, almost 100 times as long as humans have been around. But they were utterly wiped out. Only the birds survived. Pterosaurs, the flying reptiles, also vanished. So did the sea reptiles. Except for the turtles, which somehow survived. And it was the end of the road for the ammonites, those spiral-shaped creatures, relations of today's octopus and squid.

How did this happen?

About 65.5 million years ago, a humungous asteroid hurtled towards the Earth at unimaginable speed. As this dark chunk of deadly rock and ice made its final approach, planet Earth

would have looked like a sparkling blue and green jewel in the black sea of space. Down came the asteroid, possibly splitting up into several pieces before finally smashing into an unsuspecting world.

> “HOW APPROPRIATE THAT THE LARGEST ZOOLOGICAL GIANTS SHOULD HAVE BEEN FELLED BY ANOTHER, BUT MINERAL GIANT.”
>
> Richard Fortey, author of *Life: A Natural History of the First Four Billion Years of Life on Earth*

Asteroids, meteorites and comets fall from the skies even now in a constant rain. But usually they break and burn up as they cut through the Earth's thick, heavy air. You can sometimes see them for yourself on a clear night. They are commonly called shooting stars. But this was no ordinary shooting star. This thing was about six miles wide – that's the size of a large city!

It hit the Earth with the force of thousands of nuclear bombs exploding all at once, blasting a crater more than a hundred miles wide. Everything in a 600-mile-wide area was wiped off the map in seconds, leaving behind a cloud of deathly, hot, toxic gas.

“The noise and sight of the impact would have deafened and blinded countless living creatures. Many of those not killed by the blast would have been drowned by giant waves the impact created in the seas. For perhaps as long as a year the Earth was pitch dark as the sun was blacked out by thick heavy clouds of rock and dust. Plants all over the world died from lack of sunlight. Even on the opposite side of the globe from the impact, animals died of starvation.

Dinosaur times were over, just like that.

Mammals were quick off the block once the dinosaurs were gone. Well, it seems quick when you're moving through time as fast as we are. Within three million years of the meteorite disaster, shrew-sized mammals had evolved into creatures as large as dogs. Within five million years, mammals of all shapes and sizes roamed the land. This period, from 56 to 34 million years ago, is called the Eocene. (Eocene means 'New Dawn' in ancient Greek.)

> "THE FOSSIL RECORD SHOWS THAT MAMMALS CAME TRULY INTO THEIR OWN AFTER THE DINOSAURS DISAPPEARED ABOUT 65 MILLION YEARS AGO."
>
> Colin Tudge,
> author of *The Variety of Life*

The time on our 24-hour clock of Earth history shows it's between 11:42 and 11:50pm. Exotic mammals began to fill up all corners of the globe. The ancestors of modern mammals came onto the scene. There were carnivorous predators such as *Andrewsarchus*, the largest land carnivore that ever lived. It looked like a wolf but was 22 times the size of its modern cousin. Even bigger was the 'thunder beast'

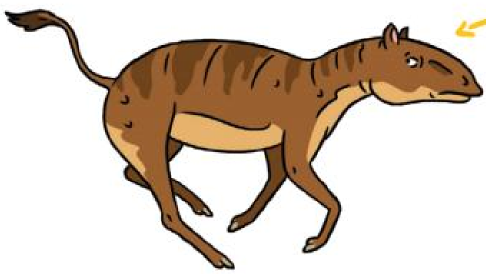

Gibbon

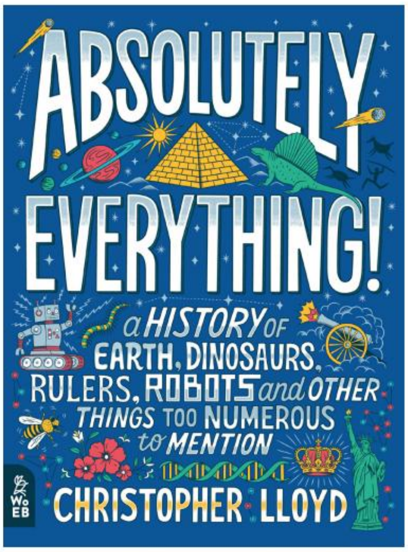
Megacerops. It was a huge plant eater that looked like a rhinoceros but was the size of a modern elephant. But not all early mammals were gigantic. The first horses appeared then, too. One was *Hyracotherium*, which was only as big as a middle-sized dog.

There's one group of Eocene mammals which is of very special interest to us. In fact, creatures from this group will become the main focus of the next part of our story. Modern primates include monkeys and apes, lemurs and aye-ayes. But the first primates looked more like squirrels than like any modern primate.

Monkeys themselves emerged about 25 million years ago in Africa. There are two main types of monkeys. The first to appear were Old World monkeys. But then one or more groups of African monkeys somehow crossed the Atlantic. It's a bit of a mystery how they did it. Some experts think they found themselves bobbing on a raft across the Atlantic Ocean, eventually to be washed ashore on the coast of modern-day Brazil.

These New World monkeys of South America have flat noses and use their tails to help them swing and balance in the trees. Some species can happily hang from a branch by their tailbone alone.


Hyracotherium



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A History of Earth, Dinosaurs, Rulers, Robots and Other Things Too Numerous to Mention

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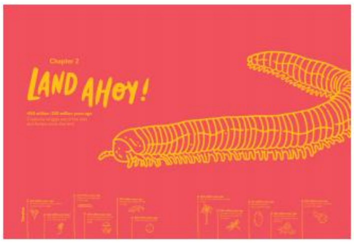

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